PHYSICAL ACTIVITY, CARDIORESPIRATORY FITNESS, MEMORY, AND SELF-EFFICACY IN THE AGING BRAIN

BY

AMANDA NICOLE SZABO

DISSERTATION

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in Kinesiology
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2012

Urbana, Illinois

Doctoral Committee:

Professor Edward McAuley, Chair
Associate Professor Charles Hillman
Professor Wojtek Chodzko-Zajko
Professor Arthur Kramer
Professor Neal Cohen

Abstract

Older adults are the fastest growing segment of our population (United Nations Populations Division, 2010). Memory is one of many important functions that declines with age and plays an influential role in health and wellbeing of older adults (Salthouse, 2003). Numerous studies have been conducted investigating the effect of self-efficacy on physical activity (e.g., McAuley, Elavsky, Jerome, Konopack, & Marquez, 2005; McAuley et al., 2006) and cognitive parameters (e.g., Serra, Dunlosky, & Hertzog, 2008) in healthy older adult populations. Self-efficacy refers to one's beliefs about his or her ability to perform a specified task or participate in an activity (Bandura, 1977, 1997). However, the specific brain regions associated with self-efficacy and the implications such brain regions may have for memory task performance are unknown. In addition to self-efficacy, previous research has demonstrated that cardiorespiratory fitness (Colcombe, Kramer, McAuley, Erickson, & Scalf, 2004; Erickson et al., 2011; Kramer et al., 1999) and physical activity (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008; Flöel et al., 2010) also can increase or help maintain cognitive function and brain health in older adults.

The purpose of this study was to determine which brain regions are associated with self-efficacy cognitions using functional magnetic resonance imaging (fMRI). In addition, a goal was to determine the relationship among these brain regions, memory performance, physical activity and cardiorespiratory fitness. Results showed, that the retrosplenial, anterior cingulate (ACC), dorsal medial prefrontal cortex (dMPFC), temporal parietal junction (TPJ), and the ventral medial prefrontal cortex (vMPFC) (van Overwalle, 2009; Buckner et al., 2008) brain regions were all active during the self-referential task. In addition, greater activity in the form of deactivation in the dMPFC was related better performance on the relational memory task.

Results also showed that the two activity groups (high and low active) overall did not have any significant differences in brain activity, however, there was a trend towards individuals in the high activity group having more deactivation in the dMPFC than individuals in the low activity group. In addition, correlation findings showed that higher self-efficacy was related to better performance memory task, greater cardiorespiratory fitness, greater participation in physical activity, greater activation in the ACC and deactivation in dMPFC. Results also showed that deactivation in the dMPFC was associated with better memory task performance and greater participation in physical activity. Finally, findings showed that physical activity, cardiorespiratory fitness, self-efficacy and brain activation on memory performance together did not influence performance on the memory task (proportion of correct responses and dprime).

This research extends the social cognitive neuroscience literature by identifying regions of the brain associated with self-efficacy cognitions relative to memory performance using fMRI. In addition, this study also provides initial insight into the role of social cognitive brain regions and how they are related to physical activity, cardiorespiratory fitness and how these variables influence cognitive health in older adults.

Acknowledgements

This study was supported by a grant from the National Institute on Aging (Award #5R37AG025667-07) awarded to Dr. Arthur Kramer and Dr. Edward McAuley.

I would first like to thank my advisor, Dr. Edward McAuley for all of your support and guidance. I am so thankful for your time and commitment to me and I hope to one day be able to provide the same guidance and mentorship you have provided me with to other students and scientists. Without your help and perseverance to always make me a better person and scientist I would not have the success and opportunities for the future I have today.

I would also like to thank my dissertation committee members, Dr. Neal Cohen, Dr. Charles, Hillman, Dr. Arthur Kramer, and Dr. Wojteck-Zajko for their guidance and encouragement.

Thank you to all of the current and past members of the Exercise Psychology Laboratory: Thomas Wójcicki, Dr. Emily Mailey, Neha Gothe, Erin Olson, Jason Fanning, Sean Mullen, Susan Herrel, Dr. Ruth Sosnoff, Dr. Katherine Hall, Dr. Liang Hu, and Dr. Shawna Doerksen. We have had some great times together, both early in the morning and late at night, which I will never forget. I am glad that I have had the opportunity to work with and learn from you all.

I also want to thank Michelle Voss, Ruchika Parkash, and Kirk Erickson, for their patience and guidance when instructing me and mentoring me while I was gaining the skills necessary to complete this dissertation. Without your help this project would not have been possible.

I offer a special thanks the undergraduate research assistants (URAs) and exercise specialists who have worked in the Exercise Psychology Laboratory over the past year: Lizzy Awick, Sarah Eid, Jillian Gallagher, Merril Idiyalil, Elise Lee, Jordan Lee, Kelly Lesniewski, Katie Randau, Jordan Orr, Kimmi Pontarelli, Jack Purdom, John Salerno, Kyle Tanzillo, and Mark Walsh. Without your help I would still be in the lab stuffing packets, stringing accelerometers, and conducting graded exercise tests. I would especially like to thank Sarah Eid for allowing me to be her for mentor for her James Scholar project. It has truly been an honor to work with you and I hope that all of my future students can live up to the high expectations you have allowed me to set. With your perseverance, knowledge, and drive I know you will succeed at anything and everything that you set you mind to.

In addition, I would like to thank the two project coordinators from the Beckman Institute. Without you, Laura O'Keefe and Anya Knecht, I would have gone crazy scheduling participants, but your organization and willingness to help in any way possible made this project a success. I also want to thanks all of the MRI runners at the Beckman Institute for assisting with the MRIs and the other cognitive testing associated with this project: Sarah Banducci, Pauline Baniqued, Aneesh Chawla, Natalie Henry, Eric Johnson, Inge Karosevica, Matt King, Mike Kranz, Aubrey Lutz, Aki Nikolaidis, Ronvir Sangha, Aldis Sipolins, and Chelsea Wong.

Thank you to the Holly Tracy-Hearnley and Nancy Dodge, the MRI technicians at the Beckman Institute, for taking the time to carefully monitor and "run" participants for this project.

To Dennis, Nancy, and Michael Szabo, my family, I want to thank you for your support and for allowing me to be a "life-long" student. Without your love, commitment, encouragement and care I would have never made it. I especially want to thank Michael for being my friend and confidant. You have always understood me and supported me and I thank you for that. I also want to thank my grandparents Dave and Joyce Parrish, and Fern Patterson. You are all an inspiration to me. One day I hope to not only understand how and why being physically active promotes longevity, but I hope age as gracefully as you have.

Thank you Dr. Rachael Seidler and Dr. Ashley Bangert for introducing me to the world of research. Without the initial experience you provided me with I would have never found a career I enjoy, something that most can only dream about.

Last, but certainly not least, thank you to Heath. Without your confidence in me and my ability to succeed, your unending love and support, I would have never made it through this past year. I am so thankful to have you in my life and I look forward to starting our new adventure together. I love you.

Contents

CHAPTER 1: Introduction

Significance

Older adults are the fastest growing segment of our population and at risk for declines in cognitive function (Salthouse, 2003, 2009), increases in physical disability (Jette, 2006; Verbrugge & Jette, 1994), and compromised quality of life (Khaw, 1997). These declines are associated with considerable medical, social and economic burden and thus demand a better understanding of factors which prevent loss of function with age. Salthouse (2003, 2009), has demonstrated that that several cognitive functions including reasoning, spatial visualization, processing speed, and memory steadily decline with age and such declines in neurocognitive function have been shown to directly influence every day function and activity for older adults (Moody-Ayers, Mehta, Lindquist, Sands, & Covinsky, 2005; Tucker-Drob, 2011). Although many lifestyle interventions have been conducted to identify ways to maintain cognitive function with age, little is known about mechanisms through which brain health is maintained with age.

Memory is one important cognitive function which can play an influential role in the health and well being of older adults. Memory is defined as the persistence of learning in a state that is revealed at a later time as active retrieval of information about an experience (Squire, 1987). Within the memory literature, working memory and episodic memory have been shown to have the greatest decline with aging (Tulving & Craik, 2000). However, it is unclear which mechanisms, behaviors, or other factors are important for preserving memory function or ameliorating cognitive decline in healthy older adults, thereby allowing them to remain productive members of society.

Previous research conducted in rodents has established the role of the hippocampus as an important region for memory functioning and aging (Rosenzweig & Barnes, 2003). Likewise, human researchers have also validated the importance of the hippocampus for memory task performance (Dennis et al., 2008; Ranganath, Cohen, Dam, & D'Esposito, 2004). Within the human literature, working memory and episodic memory are the functions most influenced by aging. Working memory is defined as the ability to actively hold information in the mind that is necessary for performing complex tasks such as reasoning, comprehension and learning. Episodic memory is concerned with remembering autobiographical events (i.e., times, places, associated emotions, and other contextual knowledge) that can be explicitly stated. Research using working memory and episodic type tasks has demonstrated that performance may be related to function or volumetric changes within the hippocampus (Gazzaley, Cooney, Rissman, & D'Esposito, 2005), as this region is important for the encoding and retrieval of memories and is sensitive to the effects of aging (Daselaar, Fleck, Dobbins, Madden, & Cabeza, 2006; Davachi & Wagner, 2002; Yonelinas et al., 2007). In addition, to working and episodic memory a more complex form of memory, relational memory, or one's ability to bind portions of an experience together (i.e., pairing a smell with an event or a face with a scene) in order to improve memory retrieval, is also impacted by the aging process, as it too heavily relies on hippocampal function (Cohen et al., 1999; Giovanello, Schnyer, & Verfaellie, 2004; Konkel & Cohen, 2009).

Both cardiorespiratory fitness and being physically active have been reported to have a beneficial effect on the cognitive function, including memory, in older adults. Specifically, cardiorespiratory fitness is associated with maintenance of cognitive function with age (Newson et al., 2009; Erikson et al., 2009; Voss et al., 2009) and interventions to increase cardiorespiratory fitness have demonstrated that increases in fitness can improve or help maintain cognitive function in older adults (Kramer et al., 1999; Colcombe & Kramer, 2003; Erickson et al., 2011). Similarly, physical activity has been associated with the preservation of cognitive function (Bixby et al., 2007; Eggermont, Milberg, Lipzitz, Scherder, & Leveille, 2009; Newson, 2006b). Increased physical activity as a function of participating in exercise programs has also been associated with improved cognitive functioning in older adults (Chang, Nien, Tsai, & Etnier, 2010; van Uffelen, Chin A Paw, Hopman-Rock, & van Mechelen, 2008). However, it is unclear whether physical activity participation and cardiorespiratory fitness have independent effects on cognitive function and can help preserve memory function with age.

One social cognitive factor that has been associated with both cognitive function and physical activity is self-efficacy (Bandura, 1997). Self-efficacy refers to one's beliefs about his or her capability to successfully perform a specified task or participate in an activity and therefore, can be used as a method of behavioral regulation or change (Bandura, 1977, 1997). Self-efficacy has been shown to influence physical activity participation, as well as be enhanced by physical activity participation (McAuley & Blissmer, 2000). In addition, cognitive performance, especially on challenging cognitive tasks (e.g., Serra, Dunlosky, & Hertzog, 2008), is also enhanced by having high self-efficacy.

Although the relationship between self-efficacy and cognitive function has been established, the specific brain regions associated with self-efficacy cognition or their implications for cognitive performance and brain health are not known. Social cognitive neuroscience is a new and emerging field of research that combines neuroscience methods, such as functional Magnetic Resonance Imaging (fMRI), to investigate social psychological phenomena, such as self-referenced behavior (Ochsner & Lieberman, 2001). Within this new field, researchers have examined self-referential behaviors such as action monitoring and self-perception. These behaviors are associated with activation in the medial prefrontal cortex (MPFC) and the temporal-partietal junction brain regions (TPJ), as well as the default network or resting state network (Buckner, Andrews-Hanna, & Schacter, 2008; van Overwalle, 2009). Whether these brain regions are also associated with self-efficacy cognitions remains to be determined.

To this end, the purpose of this study was to examine whether relationships among brain activity, cognitive function and self-efficacy are moderated by fitness/activity level with the goal of extending the social cognitive neuroscience literature by identifying regions of the brain associated with self-efficacy cognitions relative to memory performance using fMRI. In addition, the purpose of this study was to determine if these brain regions are related to physical activity and cardiorespiratory fitness, both of which have been associated with cognitive function in older adults.

Objectives and Hypotheses

Objective 1

The first objective of this study was to identify which brain regions were associated with self-efficacy during the performance of a self-referential task in the MRI and to determine how the identified ROIs were related to memory performance on a relational memory task (Dennis et al., 2008).

Based on the reviews by Van Overwalle (2009) and Buckner (2008) it was hypothesized that ROIs associated with self-referential task (i.e., retrosplenial cortex, anterior cingulate, dorsal MPFC, JPJ, and ventral MPFC) and the default network (i.e., posterior cingulate, frontal medial cortex, middle temporal gyrus, middle frontal gyrus, and the parahippocampal gyrus), would be active during the performance of the self-referential task. Also, it was hypothesized that these ROIs would be significantly related to performance on the memory paradigm. Specifically, better memory performance (i.e., greater proportion of correct responses and *d* prime score) would be associated with greater activation in all self-referential ROIs.

Objective 2

The second objective of this study was to determine whether cardiorespiratory fitness and physical activity participation, base on high and low physical activity groups, is independently associated with brain activity in the ROIs related to self-efficacy and how these factors influenced memory performance.

Based on the previous research on physical activity's effect on self-efficacy (McAuley & Blissmer, 2000; McAuley et al., 2005) and self-efficacy's relationship with cognitive function (Bandura & Wood, 1989; Serra et al., 2008; West, Bagwell, & Dark-Freudeman, 2008), it was hypothesized that the ROIs for both the self-efficacy task (i.e., retrosplenial cortex, anterior cingulate, dorsal MPFC, TPJ, and ventral MPFC) and during rest (i.e., posterior cingulate, frontal medial cortex, middle temporal gyrus, middle frontal gyrus, and the parahippocampal gyrus) would show greater activity for the individuals in the high active group as compared to the low active group. Additionally, it was hypothesized that those individuals in the high active group would also perform better on the memory task and that enhanced performance would be positively related to activation in the self-reflective ROIs, as well as the default network.

Chapter 2: Literature Review

Introduction

Older adults, those sixty-five years and older, represent the fastest growing segment of many populations around the world (United Nations Populations Division, 2010). This rapid aging of our population has medical, social and economic implications as these individuals decline in both physical and cognitive functioning. Memory is one of many cognitive functions that substantially decline with age and can have a negative impact on health for older adults (Salthouse, 2009). Physical activity is one health behavior intervention that has proven to be effective in maintaining or improving cognitive function in older adults, however the direct mechanisms underlying this effect have yet to be determined (Erickson et al., 2011; Kramer et al., 1999). For example, it is unclear whether it is cardiorespiratory fitness or physical activity, which drives this relationship (Angevaren et al., 2008). Moreover, having high self-efficacy has also been associated with better memory performance in older adults (West et al., 2008); however, more research is necessary to provide insight to why self-efficacy, cardiorespiratory fitness, and physical activity participation all have a positive impact on cognitive function with age and how these factors influence one another.

This chapter will present the current state of the literature on memory and aging including how different types of memory (i.e., procedural memory, perceptual representational systems memory, working memory, semantic memory, episodic memory and relational memory) are studied and the role of different brain regions in memory processes. Additionally, this chapter will review the literature relative to physical activity, cognitive function and brain health and how these findings compare to those of cardiorespiratory fitness, cognitive function, and brain structure/function. Next, the relationship between self-efficacy and physical activity, as well as between self-efficacy and cognitive function will be reviewed. Finally, the relationship between an emerging body of literature related to social cognitive neuroscience and the potential role of self-efficacy within this field will be summarized. The chapter will conclude with statements related to the limitations of the current research within each presented topic and will establish the role of the current project in the literature to show how self-efficacy, cognitive function, physical activity, and cardiorespiratory fitness are important to brain health and aging.

Memory and Aging

The human brain undergoes many structural and functional changes throughout the lifespan. Magnetic resonance imaging (MRI) studies, as well as postmortem assessments of brain volume (Courchesne et al., 2000; Riddle, DonLevy, & Lee, 2010), have shown that grey matter starts to slowly decline early in adult life. White matter, on the other hand, increases until adulthood and then remains stable until later in adulthood, when significant decline is observed (Ge et al., 2002; Gogtay et al., 2004). The prefrontal and frontal lobes show increased age-related decline in volume in comparison to other brain regions (Resnick, Pham, Kraut, Zonderman, & Davatzikos, 2003). Reductions in volume in these regions may be specifically associated with declines in attention, response inhibition, processing speed, and memory (Salthouse, 2003, 2009).

Memory function is made up of five independent domains that include procedural memory, perceptual representational systems memory, working memory, semantic memory, and episodic memory (Tulving & Craik, 2000). Procedural memory refers to the type of memory that is needed to acquire and perform cognitive and motor skills. Perceptual representational systems memory is responsible for one’s ability to encode and retain sensory information. Procedural and perceptual representation memory are said to be implicit, require little effort to access in order to remember, and generally are fairly resilient when it comes to aging. Semantic memory refers to general knowledge of the world and this too is fairly age resistant. Working memory and episodic memory, on the other hand, are said to be explicit and tend have the greatest decline in function as a result of aging. Working memory refers to one's ability to hold and remember information for a short period of time, while episodic memory is one's ability to remember events and experiences. Both working memory and episodic memory appear to be the most important types of memory for everyday life and are the most often studied (Balota, Dolan, & Ducheck, 2000; Luo & Craik, 2008; Zacks, Hasher, & Li, 2000). In addition, relational memory, which reflects one's ability to bind portions of a memory together (i.e., pairing a smell with an event or a face with a scene) in order to improve memory retrieval, is also an important element of memory research (Cohen et al., 1999; Giovanello et al., 2004; Konkel & Cohen, 2009).

Research findings have clearly established that memory processes in humans significantly decline with age (Park & Reuter-Lorenz, 2009; Salthouse, 2003) and which brain regions are associated with performance on memory related tasks (Rajah & D'Esposito, 2005; Small, Tsai, DeLaPaz, Mayeux, & Stern, 2002). In Salthouse's (2003) summary article exploring memory and aging, he establishes that age-related deficits in memory are not restricted to a single type of task (i.e., delayed or immediate, procedural, working, etc.) but rather occur globally and in conjunction with declines in other cognitive process (i.e., executive function). Park and Reuter-Lorenz (2009) also noted this, but recognize that verbal ability, which may be more knowledge based, does not decline as do other processes with age. In addition, Salthouse (2003) suggests that age-related declines in memory are not necessarily due to age-related increases in performance variability, but rather due to a shift in the distribution of everyone's memory with age (i.e., not related to only a small proportion of the sample experiencing a decline in memory function, but instead everyone experiences a decline in memory ability). This shift may also be a function of increases in processing speed (Park & Reuter-Lorenz, 2009; Salthouse, 2009).

Researchers have suggested that the established declines in memory function may be related to functional declines in the hippocampus and prefrontal brain regions. Small and colleagues (2002) note that fMRI signal strength for the dentate gyrus, subiculum and entorhinal cortex (regions of the hippocampus) steadily decline with age. In addition, these declines in hippocampal signal are also associated with declines in memory performance, but not with declines in abstract reasoning or language. Along with, functional declines in the hippocampus, declines in memory with age are also related to functional declines in the prefrontal cortex. Specifically, Rajah and D'Esposito (2005) reviewed the literature related to positron emission topography (PET) and fMRI and reported that the declines in memory associated with age may be due to a reduction in hemispheric specialization of cognitive function in the frontal lobes that may be related to dedifferentiation of function, deficits in function, and/or a reorganization and compensation within the brain. These functional changes in the brain are then associated with declines in episodic and working memory in older adults.

In addition to the brain structure changes in the prefrontal region that are related to working and episodic memory, relational memory function also declines with age. Traditionally, relational memory paradigms result in improved memory performance, as they allow individuals to pair stimuli together. However, this ability tends to exponentially decline with age, as the hippocampus is required for the effective "binding" of stimuli (Cohen et al., 1999; Giovanello et al., 2004; Ranganath, Heller, Cohen, Brozinsky, & Rissman, 2005). For example, one task of relational memory for face and scene stimuli (Dennis et al., 2008) has shown that younger adults performed better than older individuals which suggests that relational memory is also impaired with age. Dennis and colleagues (2008) also report that individuals were most accurate on faces, scenes and then the face-scene pairs, suggesting that face scene-pairs are more challenging to remember. Also, older adults had a longer response time than younger adults. These findings demonstrate that the ability to recognize faces and scenes decline with age and may be related to particular functional or volumetric changes within the brain. For relational memory type tasks, research has established that that the hippocampus plays a vital role in encoding new information (Dennis et al., 2008; Ranganath et al., 2004). In addition to encoding, fMRI studies have also shown that the hippocampus is important for memory retrieval (Eldridge, Knowlton, Furmanski, Bookheimer, & Engel, 2000). The medial temporal lobe has also been suggested to be important for both the encoding and retrieval of memories, especially when someone is asked if something is familiar or not (Dennis et al., 2008; Montaldi, Spencer, Roberts, & Mayes, 2006). In addition to the temporal lobe, cognitive tasks that include the presence of faces and places, or in the case of the relational memory task, scenes and faces have been shown to activate the “face” and “place” specific regions of the brain during memory encoding (Wheeler, Petersen, & Buckner, 2000). The fusiform face area (FFA), on the right side of the brain, is typically activated whenever an individual is presented with a face or is asked to remember a face (Prince, Dennis, & Cabeza, 2009). Specifically, within the hippocampus, the para-hippocampal place area, responds in a similar fashion to places (Gazzaley et al., 2005). These regions are important to the encoding and retrieval of memories and are sensitive to the effects of aging (Daselaar et al., 2006; Davachi & Wagner, 2002; Yonelinas et al., 2007). Thus, although research has established that memory globally declines with age, the brain regions affected may be related to the specific type of memory being tested.

Animal research has also established the role of the hippocampus and other associative brain regions and their role in memory and aging. Findings in animals also provide insight into which biological changes occur with age that may cause declines in memory function. A review by Rosenzweig and Barnes (2003) on age-related plasticity deficits and its effect on memory suggests that changes in the dynamics of the hippocampal network do occur with age. In rats, the CA1 region has been shown to be impaired specifically, since this is the hippocampal region that has been suggest to store sequences and location memories. Disruption of the CA1 area places aged rats at a spatial-learning disadvantage relative to younger adult rats, leading to slower (or poorer) learning of spatial tasks and faster forgetting. Similarly, delayed realignment of the hippocampal network might also cause impairment in the performance of some spatial tasks. This impairment forces aged rats to be overly dependent on self-motion information, or the response that is being made. This loss of function impairs the use of external environmental cues to correct hippocampal estimates of incorrect spatial positions. For example, Barnes and colleagues (1980) examined strategies used by older rats to remember the location of a food reward in the three-armed maze. They found that older rats tended to use a response strategy, where if during training the food was always to the right, the rat would still turn right during the test phase, even if the food was located to the left. This type of egocentric response is striatum dependent and does not rely on the hippocampus. Barnes et al. (1980) also found that younger rats, on the other hand, tended to use a cue response to locate food in a three-armed maze, a response which relies on environmental cues and is hippocampal dependent. These findings suggest that aging results in disruption of the hippocampal network where impaired encoding of context may also lead to impaired behavioral responses to contextual information for memory performance. In addition, aged rats are also impaired in contextual fear-conditioning task performance, but unimpaired in associating the conditioned and unconditioned stimuli (Oler & Markus, 1998). This disruption in the ability to perform spatial and fear-conditioning tasks, could be due to age-related changes in hippocampal network function (D. Barnes, Yaffe, Satariano, & Tager, 2003).

In vitro research in rodents has suggested that memory impairment with age may be related to both long-term potentiation of neurons (LTP; i.e., long-lasting enhancement in signal transmission between two neurons) and long-term depression (LTD; i.e., the activity-dependent reduction in the efficacy of neuronal synapses)(Barnes & McNaughton, 1985). Research on LTP suggests that memory improvements may be the result of repeated stimulation from a variety of neurotransmitters, which in turn cause changes in the formation of neuronal proteins resulting in an increase in synchronous firing of the neurons involved (Collingridge, Kehl, & McLennan, 1983; Hillman, Gupta, Stairs, Buonanno, & Dravid, 2011; Huang & Kandel, 1994; Kang & Schuman, 1996; Lu et al., 1997). LTD, on the other hand, may be responsible for the pruning of neuronal connections with age, which may result in impairments in learning as well as memory (Popkirov & Manahan-Vaughan, 2011; Rosenzweig & Barnes, 2003; Toyoda, Zhao, & Zhuo, 2006). A variety of experiences are suggested to produce changes in the brain that may be related to LTP and LTD. Specifically, exposure to enriched environments or participation in physical activity could enhance LTP expression while decreasing LTD (Black, Isaacs, Anderson, Alcantara, & Greenough, 1990; Gould, Reeves, Graziano, & Gross, 1999; Greenough & Volkmar, 1973; van Praag, Kempermann, & Gage, 1999). However, more parallel animal-human studies need to be conducted in order to confirm that the mechanisms that exist in rats also occur in humans. Even so, these findings have lead to further mechanistic and in vivo validation and behavioral research studies in humans.

Although LTP and LTD is thought to be a critical mechanism for learning and memory, limited research demonstrating these processes in humans is available. In fact, no published works relative to LTD in humans exist due to invasive measurement techniques required (Ito, 2001). LTP in humans, on the other hand, can be explored in individuals with temporal lobe epilepsy, in which one of their temporal lobes is removed in order to control the disorder. Slice preparation of a removed temporal lobe, specifically the hippocampus region, has shown that electrical stimulation of the dentate gyrus results in sustained potentiation within the neuronal connections of the hippocampus, which suggests the presence of LTP. (Beck, Goussakov, Lie, Helmstaedter, & Elger, 2000; Chen et al., 1996; Cooke & Bliss, 2006) However, whether this potentiation is related to changes in learning and memory is unknown.

More recently, technical advances have made it possible to study LTP in awake humans by delivering a titanic stimulation through repetitive transcranial magnetic stimulation (rTMS). However, rTMS cannot be used on brain regions that are located more than 2 cm below the surface of the human skull, which unfortunately includes the hippocampus. Regardless, LTP findings in other brain regions are evidence that LTP does exist in humans and that it is important for learning and memory. Esser and colleagues (2006) combined rTMS and high-density electroencephalography (EEG) to obtain direct, noninvasive evidence for LTP in humans within the motorcortex. Specifically, these researchers found that after rTMS, EEG responses were significantly potentiated. A topographic analysis of the findings revealed that this potentiation was significant at EEG electrodes located bilaterally over premotor cortex. These findings provide a direct demonstration in humans of LTP induced by rTMS. Other researchers have also come to similar conclusions within other areas of the brain including the auditory (Clapp, Kirk, Hamm, Shepherd, & Teyler, 2005) and occipital (Teyler et al., 2005) regions of the brain and suggest that LTP induced by rTMS lasts up to one-hour (Cooke & Bliss, 2006). In each brain region LTP was also associated with task learning and memory, even though LTP in the hippocampus was not directly assessed. Despite the promise of this type of research, the ability to simply validate rodent and other animal finding relative to memory in humans is one of many reasons why it is important to study other cognitive or behavioral variables that may influence memory function and brain health with age.

Physical activity and Physical fitness: Which one influences cognitive performance?

It has been suggested that exercise may help slow decline in cognition through preservation of gray and white matter (Colcombe et al., 2006; Erickson et al., 2011; Erickson et al., 2009). However, it is unclear whether these improvements in cognition are associated with changes in physical fitness or if the participation in physical activity alone is enough to allow for cognitive maintenance with age. Physical activity is referred to as any bodily movement produced by the contraction of skeletal muscles (Caspersen, Powell, & Christenson, 1985; Pate, 1995). These actions result in a substantial increase in energy expenditure above resting metabolic levels. Physical activity is also referred to as a behavior not an attribute of a person. Cardiorespiratory fitness is defined as an attribute of an individual, rather than a behavior. It reflects the capacity of the body to do physical work (Bray et al., 2009; Shepard & Bouchard, 1994; Shepard & Bouchard, 1995). Cardiorespiratory fitness is influenced by hereditary factors, as well as life-style, such as participating in physical activity (Bray et al., 2009). However, it is uncertain whether cardiorespiratory fitness or physical activity are independently associated with cognitive function as we age.

Physical Activity and Cognitive Performance

For decades, researchers have tested the efficacy of various interventions for enhancing cognitive functioning in older adults. One approach examines cognitive and lifestyle interventions that may ameliorate age-related cognitive decline. Specifically, physical activity behavior has been consistently attributed to better health in older individuals, however, it was not until the late 20th century that physical activity was also attributed to better cognitive performance in older individuals as well. Spirduso and Clifford (1978) first introduced the concept when they reported that older athletes performed better on choice reaction time task than non-athletes.

Several researchers have conducted cross-sectional studies to determine the nature of the relationship is between aging, physical activity, and cognitive function (Bixby et al., 2007; Eggermont et al., 2009; Newson, 2006b). Newson and Kemps (2006b) examined the relationship between physical and cognitive activity and its impact on cognition in older adults. Physical and cognitive activities were assessed by having older adults record the amount of physical or cognitive activity engaged in, as well as, how often and to what extent they participated in it. Better performance on both the simple and complex imagery task was associated with greater participation and more intense physical activity. This suggests that older adults who participate in physical activity for long periods of time or at a high intensity show cognitive benefits from it. Bixby et al. (2007) examined the relationship between physical activity, executive function, and advancing age. Results suggested that physical activity explained a significant amount of variance on the Stroop task performance after controlling for intelligence and age, but did not influence task performance on other measures with smaller executive function components.

Overall, these findings suggest that physical activity participation is associated with better cognitive function.

The MOBILIZE Boston Study (Eggermont et al., 2009) reported similar findings in a large (N=544) cohort study. Results showed that individuals who were in the least active group (1st quartile) based on the Physical Activity Scale for the Elderly (PASE; Washburn, Smith, Jette, & Janney, 1993) performed worse on several measures of cognitive function (i.e., clock in box drawing test, animal fluency, trail making tests, and the Hopkins verbal learning test) than those in the more active quartiles. Together, all of these cross-sectional studies suggest that being more physically active is positively associated with better cognitive function in older adults.

In addition to the cross-sectional work on physical activity and cognitive function, a number of longitudinal investigations of this relationship in older adults have also been conducted. Using data from a large national sample of older adults (NHANES III), Gillum and Obisesan (2010) found that higher leisure time physical activity was significantly associated with cognitive function at baseline and significantly predicted survival at follow up, 8.5 years later. Those individuals who were more physically active also had higher cognitive functioning at follow-up as well as a reduced risk of mortality. Similar findings were also established by Weuve and colleagues (2004) as part of the Nurses Health Study who reported that being more physically active was associated with better cognitive performance; those individuals who were in the two highest physical activity quintiles experienced less cognitive decline 2-years later at follow-up. Furthermore, increases in physical activity during the 2-year follow-up period were associated with improvements in cognitive performance.

A number of studies have examined the effects of midlife physical activity on subsequent cognitive function later in life. Chang and colleagues (2010) found that those individuals who participated in physical activity more than 5 hours per week at midlife (*M age*= 51 years) had better processing, memory, and executive function, later in life (*M age*= 76 years) compared to those individuals who were active less than 5 hours per week. Lytle and other researchers (2004) reported similar findings using three exercise categories based on type of activity, frequency, and duration; “high exercise” (aerobic exercise of ≥ 30 minute duration ≥ 3 times a week); “low exercise” (all other exercise groups); and “no exercise.” These exercise levels were then compared with scores of cognitive status (i.e., Mini Mental State Exam, MMSE; Folstein, Folstein, & McHugh, 1975). Lytle and colleagues (2004) found that high exercise level at the first assessment (*M age*= 72.9 years) was protective against cognitive decline (e.g. a drop of three or more points at follow-up) during a follow-up assessment, four years later. Yaffe et al. (2001) also established that women with a greater physical activity level at baseline were less likely to experience cognitive decline, based on MMSE score, during the six to eight years of follow-up. Together, these findings suggest that midlife physical activity may contribute to the maintenance of cognitive abilities and that the relationship between physical activity and cognitive function is stable over time.

Many randomized control trials have been conducted to determine the effects of physical activity on cognitive function; however, due to the inconsistency of methods and measures coming to a consensus on the relationship is difficult (Chang et al., 2010; van Uffelen et al., 2008). Findings do suggest, however, that participation in a physical activity intervention does not have a detrimental effect on cognitive function and many result in some positive and beneficial effect on at least one aspect of cognitive function. Also, there is no consensus on whether aerobic, non-aerobic, or a combined program is more effective in producing such changes in cognitive function. In conclusion, these reviews (Chang et al., 2010; van Uffelen et al., 2008) suggest that the research is positive yet inconclusive due to the need for more consistency in the measures used to assess both physical activity and cognitive function.

Although the reviews related to physical activity interventions and cognitive function suggest that there is a positive effect of physical activity on cognitive function it is valuable to examine the independent findings of specific randomized controlled trials. A recent randomized control trial conducted by Klusmann and colleagues (2010) with older women, consisted of three groups: a computer class (cognitive activity), a physical activity class (variety of aerobic, strength, and flexibility exercises), or a control group (instructed to carry on their normal lives). Each group met three times per week for 1.5 hours for six months. Results showed that those individuals in the cognitive class and in the exercise class either improved or maintained cognitive performance, while those in the control group declined. This intervention, as well as others (van Uffelen et al., 2008), demonstrate that both cognitive and physical activity interventions can prevent cognitive decline in older adults and more conclusively suggest that randomized control trials, to increase physical activity in older adults, do result in a positive effect on cognitive function in older adults; however, additional research is warranted (Klusmann et al., 2010; van Uffelen et al., 2008).

In conjunction with the reviews and randomized control trials on physical activity and cognitive function, Colcombe and Kramer (2003) conducted a meta-analysis to examine the affect of exercise training interventions on specific domains of cognitive function. Results of this meta-analysis show that more difficult tasks benefit more from physical activity participation than simple tasks (g = 0.68, $p < .05$, for executive tasks; g = 9.461, $p < .05$, for control tasks; g = 0.426, $p < .05$, for spatial tasks; and g =0.274, $p < .05$, for speed tasks). More recently, Smith and colleagues (2010) conducted a meta-analysis to also examine the relationship between exercise training interventions and neurocognitive performance. Smith et al. (2010) reported that individuals randomly assigned to receive aerobic exercise training demonstrated modest improvements in attention and processing speed (g = 0.158; $p = .003$), executive function (g = 0.123, $p = .018$), and memory (g = 0.128, $p = .026$). Both of these meta-analyses suggest that participation in physical activity can help improve cognitive function, particularly in the domains of processing speed and executive function in older adults. The findings relative to memory, on the other hand, are less conclusive with Smith et al. (2010) reporting only a small association. Additionally, Smith et al. did find preliminary evidence that exercise training among individuals with mild cognitive impairment (MCI) may be associated with greater improvements in memory relative to those among non-cognitively compromised samples that Colcombe and Kramer (2003) investigated.

More recently, researchers have begun to examine factors that may mediate the relationship between physical activity and cognitive performance. Flöel and colleagues (2010) reported that higher levels of physical activity (kilo-calories expended per week) were associated with not only better memory performance (i.e., Auditory verbal learning test, AVLT), but also with greater levels of the neurotropin granulocyte colon-stimulating factor (G-CSF). This neurotropin has been suggested to be a mediator of learning and memory (Schneider et al., 2005). Flöel and colleagues, however, did not conclude that brain derived neurotropic factor (BDNF), which has been previously shown to be associated with cognitive performance in rodents (van Praag et al., 1999; Vaynman & Gomez-Pinilla, 2005), was associated with memory performance in older adults. Additionally, Flöel et al. (2010) established that physical activity participation was significantly associated with gray matter volume in the right anterior frontal cortex when controlling for age, sex, education, and other health behaviors. Although the researchers also measured physical fitness, none of the measures were significantly associated with memory performance, neurtropic factors, or gray matter volume.

In summary, the findings from the physical activity, cognitive function, and brain literature suggest that physical activity participation is correlated with higher cognitive function, physical activity level/ amount earlier in life may be related to cognitive function later in life, and physical activity is also related to G-CFS level and gray matter volume in older adults, which may mediate the physical activity/ cognitive function relationship. Thus, these studies illustrate that participation in physical activity, regardless of whether it increases cardiorespiratory fitness or not, is associated with better cognitive function in older adults.

Cardioresperatory Fitness and Cognitive Performance

The literature examining the relationship between cardiorespiratory fitness and cognitive function suggests that the maintenance of cardiorespiratroy fitness with increasing age is a key factor in preserving brain structure, function, and cognitive performance. However, the associated neural mechanism by which increased cardiorespiratory fitness results in increased cognitive performance with age is yet to be determined.

Van Boxtel and colleagues (1997) conducted a cross-sectional examination of individuals ranging from 29 to 74 years of age. They reported that although both cardiorespiratory fitness and cognitive function decline with age, the decline in cognitive function was moderated by physical fitness. That is, those individuals who were more fit with increasing age maintained cognitive function. Newson and Kemps (2006a) also found that having greater cardiorespiratory fitness has a positive impact on several cognitive tasks and accounts for differences in task performance relative to age on single-component cognitive tasks like attention, working memory and processing speed, and multiple-component tasks such as executive function and memory.

Together, these findings suggest that higher cardiorespiratory fitness may act as a buffer for cognitive decline with age.

Colcombe and colleagues (2006) reported that higher cardiorespiratory fitness was associated with greater white and gray matter density, particularly in regions that are sensitive to age-related structural decline. Marks et al. (2007) found similar results for white matter tracts in the brain using diffusion tensor imaging (DTI). In addition to white and gray matter structure, cardiorespiratory fitness has also been shown to be related to cognitive function and cerebrovasuclar health in older (postmenopausal) women (Eskes et al., 2010). Pontifex, Hilman and Polich (2009) using electroencephalography (EEG) during an oddball task, showed that task performance, as well as event related action potentials during task performance, indicate that physical fitness may ameliorate or protect against cognitive aging for simple stimulus discriminations. Researchers have also reported that regional difference for cortical recruitment relative to task activity and attentional control (Colcombe et al., 2004; Parkash et al., 2011), and the brain's resting state network and functional connectivity (Voss, Erickson, et al., 2010) is maintained as a function of cardiorespiratory fitness. Specifically, such functional connectivity relationships have been related to activation in the middle frontal gyrus, superior parietal lobe, visual cortex, and anterior cingulated cortex.

Erickson et al. (2009) have shown that cardiorespiratory fitness has a positive association with spatial working memory performance and hippocampus volume in older adults. Szabo et al. (2011) have extended these findings by suggesting that higher levels of fitness not only show greater preservation of hippocampal volume which, in turn, is associated with more accurate and faster spatial memory performance, but are also related to fewer reported episodes of forgetting. This study demonstrates that memory and the regions of the brain supporting memory are directly associated with cardiorespiratory fitness, and are also related to older individuals self-perceptions of their memory abilities. In conclusion, the cross-sectional findings suggest that higher cardiorespiratory fitness is not only associated with cognitive function, but also plays a role in the maintenance of brain structure and function with age.

Relative to longitudinal research examining the association between cardiorespiratory fitness and cognitive function, Barnes et al. (2003) conducted a treadmill exercise test to assess cardiorespiratory fitness. Six years after the baseline, a battery of cognitive tests was administered. Results showed that lower baseline cardiorespiratory fitness was associated with lower cognitive function scores at follow-up suggesting that higher levels of cardiorespiratory fitness may help to preserve cognitive function with age.

Randomized controlled trials have also demonstrated that increasing cardiorespiratory fitness through a structured physical activity program results in improvements in cognitive performance in older adults. In an early study, Dustman et al. (1984) had older adults complete a graded exercise test (GXT) to assess cardiorespiratory fitness as well as baseline neuropsychological function. Participants were then randomized into three groups, one for aerobic exercise, another for anaerobic exercise, and the third was a non-active control. Participants in the exercise groups completed three one-hour mode specified exercise sessions per week for four months. All baseline testing was repeated again after 4 months. Results showed that the aerobic group participants' cardiorespiratory fitness increased more than those in the anaerobic group and non-active group, as did neuropsychological performance. Depression scores, sensory thresholds, and visual acuity were not changed by aerobic exercise participation. These results suggest that aerobic exercise training associated with changes in cardiorespiratory fitness may also bring about improved cognitive performance in older adults. Building on

Dustman's findings, Kramer et al. (1999) conducted a 6-month intervention with older adults randomly assigned to participate in either aerobic or anaerobic exercise. Pre-and post-cardiorespiratory fitness was assessed along with cognitive task performance on a task-switching paradigm as a measure of executive function. Cognitive task performance as well as cardiorespiratory fitness increased for the aerobic participants, but not anaerobic participants. These results also suggest that cardiorespiratory fitness improvements are associated with executive type cognitive task improvement and maintenance with age.

More recently, randomized controlled trials have examined the relationship between changes in cardiorespiratory fitness from participation in structured aerobic exercise and changes in cognitive function and brain structure and function. Erickson and colleagues (2011) conducted a year-long randomized controlled trial and determined that increases in cardiorespiratory fitness are associated with increase in spatial working memory performance, which was also related to increases in hippocampal volume in older adults. In addition, similar changes in cardiorespiratory fitness have also been shown to be related to changes in the resting state network brain activity and cognitive performance (Voss, Prakash, et al., 2010). Together, these findings indicate that participation in structured aerobic exercise not only improves cognitive performance in older adults, but also improves brain structure and function in brain regions corresponding to such cognitive improvements.

A number of meta-analytic and narrative reviews on cardiorespiratory fitness and cognitive function in older adults summarize this literature. Etnier et al. (2006) conducted a meta-analysis that showed a positive relationship between cardiorespiratory fitness and cognitive performance. Overall, Etnier et al. (2006) found that there was a positive association between cardiorespiratory fitness and cognitive function (Mean r = 0.29, range .04 - .68), and concluded that small changes in cardiorespiratory fitness lead to significant and meaningful changes in cognitive function (g = 0.25). However, Etnier and colleagues did not determine the impact of cardiorespiratory fitness on the different domains of cognitive function, as others have done (Colcombe & Kramer, 2003; Smith et al., 2010).

More recently, a systematic Cochran review suggested that aerobic physical activities, which improve cardiorespiratory fitness, are beneficial for cognitive function in healthy older adults (Angevaren et al., 2008). In this review, eight of eleven intervention studies reported that the aerobic exercise condition/group in interventions result in increased cardiorespiratory fitness with corresponding improvements in cognitive performance. The largest effects on cognitive function were found on motor function and auditory attention, g = 1.17 and g = 0.50 respectively. Moderate effects were observed for processing speed, g = 0.26 and visual attention g = 0.26. However, the authors' indicated that the data were insufficient to suggest that the improvements in cognitive function, which can be attributed to physical exercise, are due to improvements in cardiovascular fitness, although the temporal association suggests that this might be the case. Together, Etnier et al. (2006) and Angevaren et al. (2008) conclude that larger studies are still required to confirm whether the aerobic training component is necessary, or whether the same cognitive improvements can be achieved with any type of physical activity. Furthermore, additional research is necessary to understand why some cognitive functions seem to improve with aerobic physical activity participation while others do not.

In summary, the literature on cardiorespiratory function, cognitive performance, and brain structure and function suggest that maintaining or increasing cardiorespiratory fitness, even in older adults, is associated with maintenance of cognitive function, brain structure, and function. However, it is unclear as to what extent the relationship is simply with cardiorespiratory fitness alone or if participation in any form of physical activity to improve health can help to improve and maintain brain health with age. It is also unclear whether other variables, such as genes, environments, or other psychosocial variables play a role in these relationships.

Social Cognitive Theory

Social Cognitive Theory (SCT; Bandura, 1986, 1997, 2004) is comprised of a core set of determinants including: psychological determinants, observational learning, environmental determinants of behavior, self-regulation, and moral disengagement (Bandura, 1986, 1989). These determinants help to explain how people acquire and maintain patterns of behavior and also provide the basis for intervention strategies. Specifically, human behavior is explained in terms of a triadic, dynamic, and reciprocal model in which behavior, personal factors, and environmental influences all interact to determine an individual's behavior (Figure 1).

The specific components of the triadic SCT model rest on the importance of human agency, which is the key mechanism through which an individual can contribute and modify outcomes (Bandura, 1989). Personal efficacy is the main component of one's personal human agency. Self-efficacy is suggested to be the "active ingredient" and it is also the most highly studied concept. Self-efficacy expectations are beliefs regarding an individuals' capabilities to successfully carry out a course of action (Bandura, 1977) and is considered to be a situation-specific form of self-confidence. The situation-specific nature of self-efficacy is what distinguishes efficacy cognitions from the other more stable qualities of general self-confidence and allows it to be easily influenced, thus making self-efficacy an ideal target for manipulation (McAuley, Talbot, & Martinez, 1999) and intervention (McAuley, Courneya, Rudolph, & Lox, 1994; McAuley et al., 2010). The primary sources of efficacy information include past performance accomplishments, or mastery experiences, social persuasion, social modeling, and the interpretation of physiological and emotional states (Bandura, 1997). Efficacy expectations are theorized to influence the activities that an individual chooses to pursue, the degree of effort they expend to complete a task, and the level of persistence they demonstrate in the face of related barriers. Together, choice, effort, and persistence are related to the successful adoption and maintenance of health behaviors, like physical activity, especially as one ages (McAuley & Blissmer, 2000; McAuley et al., 2010).

Self-efficacy and Physical Activity

Within the physical activity and self-efficacy literature, there is evidence to suggest that self-efficacy is one of a number of potential mediators of the effects of physical activity on several psychological outcomes (Craft & Landers, 1998; Taylor, 2000) in older adults. Self-efficacy has been identified as both a consequence of physical activity and determinant of physical activity participation (McAuley & Blissmer, 2000). Cross-sectional research has shown that the amount of physical activity one participates in is significantly related to one's confidence in his or her ability to exercise on a regular basis (McAuley et al., 2006). In addition, there is a strong association between self-efficacy and physical activity that appears to hold when a variety of measures of physical activity are used. For example, Conn et al. (2003) found adherence self-efficacy to be the best predictor of exercise frequency, as well as exercise intensity and duration. Similarly, Harris et al. (2009) found exercise self-efficacy was positively related to accelerometer-measured step count in a dose dependant manner. These findings suggest that there is a clear relationship between self-efficacy and physical activity.

Longitudinal studies have also demonstrated the role physical activity participation plays in maintaining self-efficacy levels over time as well as suggest it reliably predict future engagement and adherence to physical activity regimens. Specifically, McAuley, Lox and Duncan (1993) showed that exposure to both acute bouts of physical activity (i.e., GXT) as well as participating in an exercise intervention can both increase self-efficacy. In addition, Sallis and colleagues (1986) noted that adoption and maintenance of physical activity was significantly predicted by self-efficacy in a community sample of older adults over the course of a year. Luszczynska et al. (2007) found leisure runners who demonstrated greater recovery self-efficacy or confidence to resume running after a lapse, at baseline ran/jogged more at follow-up, two years later. Similarly, McAuley (1993) suggests that self-efficacy predicted exercise behavior over the 4-month follow-up period when statistically controlling for previous exercise participation and aerobic capacity. In addition, McAuley et al. (2007) found that adherence self-efficacy assessed two years following an exercise intervention to be a significant predictor of physical activity three years later in older adults. Together, these studies suggest that self-efficacy is a consistent determinant of physical activity for older individuals, even several years later in life.

The effect of physical activity participation and the relationship between changes in physical activity and self-efficacy has been most commonly studied through the use of exercise interventions. Most physical activity interventions have demonstrated that simply adhering to a regular exercise regimen as part of an intervention results in an increase in self-efficacy for exercise (Annesi & Unruh, 2008; Bock, Marcus, Pinto, & Forsyth, 2001; D'Alonzo, Stevenson, & Davis, 2004; Dallow & Anderson, 2003; S.-J. Huang, Hung, Chang, & Chang, 2009; Hughes et al., 2004; Katula, Rejeski, & Marsh, 2008; Katula, Sipe, Rejeski, & Focht, 2006; Li et al., 2002; McAuley, 1993). This is likely due to the accumulation of mastery experiences, which act as a primary source of efficacy information. Furthermore, theory-based interventions (e.g., SCT approach) have been shown to be more effective at increasing self-efficacy than non-theory based interventions (Bock et al., 2001; Hall et al., 2011; Hughes et al., 2004). Such theory-based interventions typically utilize strategies to increase self-efficacy, for example providing mastery experiences, facilitating social modeling, or utilizing social persuasion, in accordance with Bandura's model of triadic reciprocity (Bandura, 1986, 1989, 2004).

One example of an intervention conducted to change self-efficacy through an SCT frame work was recently conducted by McAuley and colleagues (2010). Specifically, these researchers conducted a 12-month exercise intervention for community dwelling older adults where they found that exercise self-efficacy decreased from baseline to 3 weeks, followed by a significant upturn at 6 months, and then a second, steeper downturn at the program's end. Barriers self-efficacy showed a similar pattern, although the increase in self-efficacy between week 3 and month 6 was not significant. Finally, self-efficacy for walking showed a linear trend with a significant positive increase over time that was maintained at 12 months. This study was the first to take multiple measures of self-efficacy within an exercise intervention and demonstrate that a recalibration of self-efficacy occurs in the early weeks of an exercise program. Moreover, it also appears that when judging their capabilities to adhere to regular exercise, individuals may be overly optimistic at baseline, when they have not yet undertaken the behavior. Thus, these findings suggest that measure at 3 weeks into an intervention could be considered a "true baseline" or "informed baseline," and the increases in self-efficacy exhibited between week 3 and month 6 occur as a function of regular exercise participation (i.e., mastery experiences). Additionally, the decrease in self-efficacy at 12 months is consistent with previous studies (e.g., Hughes et al., 2004; McAuley, Jerome, Elavsky, Marquez, & Ramsey, 2003; McAuley, Katula, et al., 1999), which have shown that efficacy decreases at the end of a program due to the impending challenge of maintaining an exercise regimen after the termination of the structured intervention.

Recently, McAuley et al. (2011) investigated the influence of executive function, self-regulatory behavior and self-efficacy on older adults' adherence to a 12-month exercise intervention. These researchers found that executive function, specifically tasks that reflect ones' ability to multi-task and inhibit habitual responses, as well as self-regulatory strategy use, were significantly related to self-efficacy at 3-weeks into the exercise intervention. Self-efficacy was in turn related to adherence to the exercise classes. These findings suggest that cognitive capabilities may influence self-efficacy for physical activity, which are then related to ones ability to adhere to positive health behaviors.

Self-efficacy's Influence on Cognitive Performance

Self-efficacy has also been demonstrated to influence memory and other cognitive functions. For example, significant differences in everyday memory and memory self-efficacy have been reported when comparing younger and older adults (Wells & Esopenko, 2008). Wells and Esopenko (2008) concluded that memory self-efficacy predicts memory performance on free-recall memory tasks in older adults. Similarly, Serra, Dunlosky, and Hertzog (2008) reported that older adults performed less accurately on memory related tasks than younger adults, however, older adults were able to more accurately judge their performance, since they not only performed poorly, but also reported being less efficacious about their ability to remember words. In addition to cross-sectional studies, West and colleagues (2008) conducted an intervention in an attempt to improve self-efficacy for memory and memory performance in older adults. They found that compared to waitlist control participants, older adults who received a SCT structured training intervention to improve memory strategies, used more effective techniques to complete a memory test at the end of the five week training period. Results also demonstrated that memory performance post-training was predicted by receiving the intervention, post assessment self-efficacy, and baseline memory performance. This suggests that SCT based interventions can be used to improve both self-efficacy for memory and memory performance alike. These studies further suggest that significant differences exist between older and younger individuals, relative to memory performance and their beliefs in their capabilities to perform memory related tasks and that self-efficacy may play a more important role in cognitive performance for older adults than younger individuals.

A number of studies have also examined self-efficacy's effect on executive functioning. These studies have concluded that past performance on cognitive tasks influences self-efficacy, which in turn affects ones analytical strategies, which is associated with subsequent overt performance (Bandura & Wood, 1989; Wood & Bandura, 1989). Thus, the higher one's efficacy beliefs about their own cognitive ability in a defined situation, the better the performance (Bandura, 1977; Bandura & Wood, 1989). Windsor and Anstey (2008) have reported that those individuals with higher levels of perceived control at baseline performed better four years later.

Few studies to date have examined the association between self-efficacy and brain activity. One exception is a study by Themanson et al. (2008) examining the relationship between self-efficacy, error commission (ERN), and overall performance accuracy on event related brain potentials (ERP) in older adults. Participants' completed a flanker task where speed and accuracy of performance were assessed, as well as ERPs, being collected while the subject performed the task. Participants with higher self-efficacy responded more quickly and exhibited larger ERN and Pe amplitudes for accuracy than those with low self-efficacy. These findings may suggest that self-efficacy affects action-monitoring processes in older adults or how one responds to an error.

Brain Activity and Social Cognition (Social Cognitive Neuroscience)

Examining relationships among self-efficacy, cognitive performance and brain activity may best be understood from a social cognitive neuroscience (SCNS) perspective. Ochsner and Lieberman (2001) define SCNS as a combined interdisciplinary field that involves the integration of analysis of behavior on the social level, to information-processing mechanisms on the cognitive level, and the brain systems that initiate these processes at the neural level. Butler and Senior (2007) suggest SCNS is embedded in social science, as it draws on theories and psychological phenomena including social cognition, but uses neuroscience methodology such as fMRI, PET, TMS, and ERPs to answer related questions. SCNS research has focused on the decision-making process and the cognitive processes that lead to these decisions and how these decisions are affected by an individual's desire to act, ability to act, and situational demands (Blakemore, Winston, & Frith, 2004; Lieberman, 2005; Ochsner, 2004). All of these factors have the ability to influence human behavior and possess important social outcomes. Although the SCNS literature has not specifically focused on self-efficacy, a related construct, self-reflection, has received a considerable amount of attention in the literature (van Overwalle, 2009).

Brain regions that have been linked to SCNS processes such as self-reflection, decision-making, recall, envisioning, and self-consciousness may also be associated with self-efficacy. Measures of these self-apprasial processes, have been used in conjunction with fMRI to determine brain regions that may be associated with self-reflective cognitions (Schmitz & Johnson, 2006). Previous research has indicated that the anterior and posterior cingulate, precuneous, and medial prefrontal cortex are specific brain regions involved in self-referential assessments of behavior (Hampton & O'Doherty, 2007; Schacter, Addis, & Buckner, 2007). Specifically, research has shown that participation in a self-reflective task increases activity in these specific brain regions more so than tasks that do not require self-reflection or appraisal (van Overwalle, 2009).

In addition to task specific areas of brain activity, research has also suggested that the default, or the brain's resting state network, may also plays a key role in self-reflection suggesting another area that may be implicated in efficacy expectations for cognitive performance. Default network brain regions that are suggested to be related to self-referential cognitions include areas such as ventro-medial prefrontal cortex, posterior cingulated, inferior parietal lobule, lateral temporal cortex, dorsal medial prefrontal cortex, and the hippocampus (Buckner et al., 2008). Such regions have not only been shown to be active during social cognitive tasks (Hampton & O'Doherty, 2007; Schacter et al., 2007; van Overwalle, 2009), but are also the regions employed during self-referential tasks. These findings suggest that the default or resting state network may also be involved in brain areas related to self-efficacy expectations. In addition, such brain regions have also been shown to be influenced by physical activity as well as cardiorespiratory fitness in older adults (Colcombe et al., 2006; Erickson et al., 2011; Erickson et al., 2009; Voss, Erickson, et al., 2010; Voss, Prakash, et al., 2010). However, despite the growing body of research on the default network and brain activity related to self-referential behaviors the exact relationship between these brain regions and physical activity and their relationship with self-efficacy has yet to be determined.

Limitations in the Literature

Although there is a considerable body of literature examining the relationships among aging, memory function, physical activity, cardiorespiratory fitness, and social cognitive constructs, several areas remain to be addressed. We know that memory performance; as well as associated regions of the brain are positively influenced by cardiorespiratory fitness (Erickson et al., 2011; Erickson et al., 2009). In addition, the literature suggests that having higher self-efficacy at an older age improves task performance on memory as well as other executive tasks (Serra et al., 2008; West et al., 2008). Being more physically active, and fitter is associated with greater self-efficacy (Konopack et al., 2008; McAuley et al., 2005; McAuley et al., 2006). Finally, we know that self-reflective areas of the brain, including the default network and its connectivity, are positively influenced by cardiorespiratory fitness (Voss, Erickson, et al., 2010; Voss, Prakash, et al., 2010). Whether these brain regions are specifically related to self-efficacy, how self-efficacy manifests itself in the brain and how it is related to memory performance has yet to be determined. Moreover, whether being more active or fit moderates this relationship is not known.

The Present Study

The present study aimed to identify which brain regions were associated with self-efficacy and how these brain regions were related to self-efficacy, memory performance, physical activity, and cardiovascular fitness. In order to determine this, the specific brain regions associated with self-efficacy during the performance of a self-referenced task, as well as how these areas were related to task performance on the relational memory task, were identified. In addition, the relationship between physical activity group and its association with brain activity during the self-referenced task was determined. Finally, the relationship between brain activity during the self-referenced task, self-efficacy, cardiorespiratory fitness, physical activity and their relationship with memory performance was identified. In conclusion this study was able to identify an additional moderators of cognitive function, which will in turn aid in the development of future inventions to improve quality of life and cognitive function in older adults.

Chapter 3: Research Design and Methods

Methods

Sample and Recruitment

Research participants were drawn primarily from Champaign County (population 193,636) and the surrounding areas in central Illinois. In order to adequately recruit older participants, paid, targeted advertising in local newspapers, senior magazines and e-week was employed. Additionally, we contacted the representatives of area radio stations that identify older adults as a key element of their market share. Finally, flyers were distributed at community events, organizations and facilities, which may have a large membership of highly active older adults (i.e., running clubs, tennis clubs, and other master athlete groups on and off campus). We also posted flyers in local restaurants, libraries, shops, and athletic/exercise facilities.

Participation Criteria

Participants were required to meet several criteria before entering the study. All participants were between the ages 60 to 79 years of age, and capable of participating in exercise without exacerbating any pre-existing condition(s). In addition, those individuals in the sedentary group were required to be physically active less than 2 days per week for 30 minutes or less, whereas the highly active individuals must participate in aerobic physical activity on 5 or more days per week for 30 minutes or more. All participants were screened for cognitive impairment using the 13-item modified Telephone Interview of Cognitive Status (TICS-M; de Jager, Budge, & Clark, 2003). In addition, each participant was required to have corrected (near and far) acuity 20/40 or better, including no reported color blindness, a depression score on Geriatric Depression Scale (GDS, Sheikh & Yesavage, 1986) below clinical level, no metal objects residing in their body, and could not be claustrophobic. Finally, all participants were also required to obtain written consent from their personal primary care physician to participate in this study.

Measures

Health History and Demographics. Each subject completed a standard health history questionnaire assessing medical history and lifestyle habits prior to recruitment into the study. Basic demographic characteristics on all individuals including age, education, socioeconomic status marital status and whether or not they participate in a life-long learning program were also obtained.

Mental Status. Participants were screened for cognitive decline using the TICS-M (Brandt, Spencer, & Folstein, 1988; de Jager et al., 2003). The TICS-M covers four domains of function including orientation, registration/recent memory; attention/calculation; and semantic memory/comprehension. The measure is a good assessment of mild cognitive dysfunction and is easy to administer during telephone screening. The maximum score on the TICS-M is 39 with a score of 21 being equivalent to a score below 25 on the Mini Mental Status Examination (MMSE). A score of 24 on the MMSE is considered normal (Folstein et al., 1975).

Physical Activity. Physical activity was assessed objectively by accelerometry. The Actigraph accelerometer (GT3X, Health One Technology, Fort Walton Beach, FL) is a small (1.5 x 1.44x .70 in) and lightweight (27 grams) device powered by a rechargeable Lithium Polymer battery that is capable of providing power for up to 20 days without recharging. Participants were instructed to wear the monitor on the non-dominant hip, under their clothing, and fastened to a belt worn around the waist. The accelerometer was worn during all waking hours, except for when bathing or swimming. Activity data were collected in one-minute intervals (epochs), with the total number of counts for each day summed and divided by the number of days of monitoring to arrive at an average number of activity counts.

The Actigraph demonstrates acceptable reliability and validity among young and middle-age adults (Bassett et al., 2000; Hendelman, Miller, Baggett, Debold, & Freedson, 2000; Tudor-Locke, Ainsworth, Thompson, & Matthews, 2002; Washburn, McAuley, Katula, Mihalko, & Boileau, 1999) and chronically diseased, older adults (Focht, Sanders, Brubaker, & Rejeski, 2003). Participants recorded the time that the accelerometer was worn on a log, and this was verified by the inspection of the accelerometer data. The data were further examined for long periods of continuous zeros as a check of compliance with wearing the device and a criterion of 30 minutes of continuous zeros (Copeland, 2009) suggested non-compliance. One valid day of measurement was based on 10 hours of wear time during the waking hours (Mâsse et al., 2005), from getting out of bed in the morning through getting into bed in the evening. Data were considered to be inaccurate when counts exceeded 20,000 per minute (Mâsse et al., 2005) or when participants had less than five valid days of data. The downloaded data were processed using MeterPlus (Actilife) and the movement counts for each day were summed and then averaged across the period of five valid days of data. Accelerometer data are expressed in total movement counts per day (i.e., usual physical activity).

Appropriate cut-points for activity were then applied to the data in order to determine the amount of time each participant spent performing sedentary, light, moderate, hard, and vigorous activities (Copeland, 2009; Mâsse et al., 2005). The number of counts obtained during moderate, hard, and vigorous activities were then summed to obtain a measure of moderate to vigorous physical activity (MVPA) per day for each participant.

Graded Exercise Testing (GXT). Participants completed a nurse and physician supervised GXT to assess cardiorespiratory fitness. This test was conducted on a motor-driven treadmill employing a modified Balke protocol (Balke & Ware, 1959). The protocol involved walking at a self-selected speed (slightly faster than normal walking speed) while increasing grade increments of 2% every 2 min. Measurements of oxygen uptake, heart rate and blood pressure were continuously monitored. Oxygen uptake (VO_2) was measured from expired air samples taken at 30 second intervals until a peak VO_2, the highest VO_2, were attained at the point of test termination due to symptom limitation and/or volitional exhaustion. Other evidence of maximal effort included a respiratory exchange ratio greater than or equal to 1.0 and/or a heart rate approaching the age-predicted maximum (i.e., 220-age). Heart rate was taken during each work stage through continuous direct 12-lead electro cardiographic monitoring. Blood pressure was measured by auscultation and a sphygmomanometer.

Relational Memory Task. Participants completed a modified version of the relational memory task developed by Dennis et al. (2008). This task used a hybrid event-related block design, such that timing of trials were jittered in order that remembered and forgotten items could later be traced back to examine associated brain activity. All stimuli were color images from the Ebner database (Ebner, Riediger, & Lindenberger, 2008). Participants performed three runs of approximately 10 minutes in the fMRI. Each run consisted of successive encoding-retrieval phases. In the encoding phase of a trial, participants saw a scene for 2 seconds (s) then a face superimposed on that scene (face-scene pair) for an additional 2 s. This ensured that the participant could view the whole scene before making a relationship with the face. There were 24 encoding trials. To ensure that the participant was actively forming relationships between the scene and face stimuli during the encoding phase, participants were asked to make judgments based on their past experiences of whether they would normally encounter the person in the scene presented (yes or no). Between trials there was an optimal jittered fixation-screen interstimulus interval (ISI) of 4 to 8 s as determined by opsteq2 (http://surfer.nmr.mgh.harvard.edu/fswiki/optseq2). Following a brief delay (20 s), the retrieval phase began. As during encoding,trial participants saw a scene for 2 s, followed by a face-scene pair for 2 s. All the faces and scenes shown during retrieval were also shown during encoding, therefore there were no novel items during the retrieval phase. To study brain processes related to relational memory, 12 trials were 'intact' face-scene pairs (the same face-scene pair shown at encoding) whereas the other 12 were 'repairs' (a scene and face from the encoding phase, but were not previously shown as a pair). Participants were asked to respond if a pair was 'old' or 'new.' Each block has 24 retrieval trials. Examples of stimuli and presentation for both the encoding and retrieval phases are presented in Figure 2.

A total of 72 encoding trials and 72 retrieval trials were performed over the course of the three runs. Reaction time (RT), and accuracy were recorded by the computer for each recognition trial. The total time for this task was approximately 30 minutes.

The primary outcome variables for the relational memory paradigm were calculated based on the number of hits (i.e., responding yes, to a previously viewed pair), correct rejections, and false alarms using procedures previously described by Bayer-Carter et al. (2001) and Konkel et al. (2008) to derive the proportion of correct responses and *d* prime variables.

Self-efficacy fMRI Protocol. Self-efficacy for the relational memory task was assessed using a modified version of the referenced self-appraisal task used by Schmitz and Johnson (2006). This paradigm was made up of two tasks; a memory self-efficacy (MSE) task and a non-self-referencing (NSE) task. The latter task served as a “control” task, as is uses different brain regions than the self-referential or MSE portion of the task, as indicated by Schmitz and Johnson (2006). All items for each task can be found in Appendix A and B, respectively. The MSE task required participants to make yes/no decisions based on how confident they felt they could complete "X" number of trials correctly for the face/scene relational memory task (MSE). The MSE paradigm contained twenty-four items with statements such as, "I am confident that I can correctly recognize 3 of 24 presented face-scene pairs." Participants then either responded yes or no by pressing keys on a keypad. The trials appeared in a random order to ensure a consistent oscillation of brain activity during the trials. The NSE task served as a spatial and response control and asked participants to assess their belief in whether it would rain "X" number of days of the next 24. An example of NSE trial asked "I am confident that it will rain 4 of 24 days this month". As with the MSE task, participants responded to twenty-four items by answering yes or no by pressing keys on a keypad. The trials again appeared in a random older to ensure consistent oscillation of brain activity during each trial.

For each task (MSE or NSE) eight blocks of six stimuli each were presented during a single run where participants responded to a total of 24 MSE and 24 NSE trials. MSE and NSE statements each appeared for 2.5s each, followed by a response screen for 1.5s and a fixation-screen ISI of 500ms. MSE and NSE stimuli were counter balanced across conditions and subjects whereby some participants saw MSE trials followed by the NSE trials and others were presented with the NSE trials followed by the MSE trials. This protocol took approximately 6 minutes to complete.

"Yes" responses during the MSE and NSE tasks were summed, then divided by twenty-four and multiplied by 100 to produce a score ranging from 0 to 100. This score served as an individual's total confidence in their ability to complete the relational memory task or total confidence that it would rain. In addition, the computer reported the RT for both tasks, and for yes and no responses.

Questionnaire Assessments of Self-efficacy. In addition to the self-efficacy fMRI protocol, self-efficacy for cognitive function was also assessed via two questionnaires. Zelinski and Gilewski (2004) developed a 10-item version of the 33-item Frequency of Forgetting scale (F of F) from the Memory Functioning Questionnaire (MFQ; Zelinski, Gilewski, & Anthony-Bergstone, 1990). Zelinski and Gilewski (2004) and report excellent reliability across items and persons for the shorter version of the scale. Construct validity was demonstrated by theorized relationships with depression, conscientiousness and actual memory performance (Zelinski & Gilewski, 2004). For this assessment, items were rated on a seven point Likert scale with lower ratings indicating more negative self-report, or a greater frequency of forgetting. Mean rating was calculated by summing all items and dividing by 10. This measure has also been shown to be associated with spatial working memory performance and hippocampal volume in older adults (Szabo et al., 2011).

In addition to the F of F, memory confidence was assessed using the Memory Controllability Inventory (MCI; Lachman, Bandura, Weaver, & Elliot, 1995; Lachman, Weaver, Bandura, Elliot, & Lewkowicz, 1992) The MCI consists of 12-items assessing beliefs about memory ability (i.e., present capacity, potential improvement) and memory control (i.e., role of effort, belief in inevitable decrement). These 12-items comprise four subscales: Capacity (e.g., “I can remember the things I need to”), Improvement (e.g., “I can find ways to improve my memory”), Effort (e.g., “If I use my memory often I won't lose it”), and Inevitable Decrement (e.g., “When it comes to memory, there is no way one can make up for the losses that come with age”). Ratings were made on 7-point Likert scales, ranging from strongly disagree to strongly agree. Each subscale contains three items (scoring range = 3 to 21). Previous research, based on three adult samples conducted by Lachman (1995), suggests that scale reliabilities are adequate for Capacity, α = .71, Improvement, α =.69, Effort, α = .70, and Inevitable Decrement, α = .68.

Procedures

Data Collection

Participants were first screened for all qualifying criteria, including the TICS-M over the phone. Once physicians' approval was obtained for a participant, he or she was invited to participate in the study. A questionnaire packet containing the physical activity and the self-efficacy measures (F of F and MCI) along with an accelerometer and a log to report wearing time was then mailed to the participant and returned at the GXT appointment. Participants then completed a physician supervised GXT and the fMRI protocol. All testing was completed within a span of three-weeks and no two tests were completed on the same day. For the fMRI protocol each participant first complete the pre-self-efficacy assessment (MSE and NSE), followed by the relational memory assessment.

fMRI Data Acquisition

All participants were scanned in a 3T Siemens Allegra whole-body scanner. All stimuli were presented using MRI-safe fiber optic goggles (Resonance Technologies, Inc.). T2* weighted images were acquired using a fast echo-planar imaging (EPI) sequence (64 x 64 resolution matrix, 4-mm slice thickness, TR = 1500 ms, TE = 25 ms, flip angle = 80°). Anatomical, T1-weighted images were acquired using a 3D Magnetization Prepared Rapid Gradient Echo Imaging (MPRAGE) protocol with 28 contiguous axial slices, collected in ascending fashion parallel to the anterior and posterior commissures, echo time (TE)=3.87 ms, repetition time (TR)=1800 ms, field of view (FOV)=220 mm, and voxel size of 3.4 x 3.4 x 4mm.

During the self-efficacy paradigm (MSE and NSE combined) a total of 244 total BOLD volumes were collected.

Data Analysis

Establishment of physical activity groups

The high and low activity groups were established two ways, (1) based on the a priori high and low physical activity classification determined during participant recruitment (i.e., low active individuals were identified as physically active less than 2 days per week for 30 minutes or less, high active individuals were identified as participating in aerobic physical activity on 5 or more days per week for 30 minutes or more), and (2) based on examination of the accelerometer data. The sample characteristics for the a priori low and high activity groups are presented in Table 1. Using the accelerometer data, high and low MVPA groups were established based on the amount of time spent participating in MVPA per day. Specifically, any individual in the low physical activity group who participated in one-half of a standard deviation more MVPA per day than the mean was moved to the high active group and those individuals who were in the high physical activity group, but participated in one-half of a standard deviation less MVPA than the mean were moved to the low active group. This resulted in two new groups based on MVPA (i.e., high MVPA group and low MVPA group). The means and standard deviations for the sample characteristics of these groups are presented in Table 2.

fMRI Pre-processing

All fMRI images were motion-corrected using a rigid-body algorithm in MCFLIRT (Jenkinson, 2003) and temporally smoothed with a 100s cut-off Gaussian high-pass filter. Spatial smoothing was conducted with a 7-mm (Full Width at Half Maximum: FWHM) 3-dimensional Gaussian kernel. Following this, all high-resolution T1-weigthed images were skull stripped using a robust deformable brain extraction technique (BET; Smith et al., 2002). The skull-stripped images for each participant were then spatially registered using a 12-parameter affine transformation to a study-specific template in stereotaxic space. This template was specifically created for this study to avoid systematic registration error. To do so: (a) each participant's high-resolution scan was registered to MNI space; (b) an average of these registered images was created; and (c) the average image was then spatially smoothed with a 7-mm (FWHM) Gaussian kernel. This study-specific template was then subsequently used for spatial registration of all fMRI data.

Objective 1: Associations among self-efficacy brain ROIs and memory performance

fMRI Analysis. The first goal of this objective was to identify which brain regions were associated with self-efficacy during the performance of a self-referential task in the MRI. Based on Schmitz and colleagues (2006) findings in healthy adults, it was hypothesized that significant cluster activation would be present in the retrosplenial cortex, ACC, and dMPFC. Additionally, others (e.g., van Overwalle, 2009) have suggested that the TPJ and vMPFC may also be important for self-referential cognitions such as self-efficacy. To determine which ROIs were associated with self-efficacy a series of analyses using FSL were conducted. Following pre-processing, the functional neuroimaging data collected during the presentation of memory (MSE) and non-memory self-efficacy tasks (NSE), were convolved with a double-gamma function to model the response for each condition (MSE, NSE, and rest/fixation). This first-level analysis, was conducted separately for each participant, resulting in voxel-wise parameter estimate maps for the entire brain for each condition and for the direct comparison between the conditions (e.g., MSE > NSE, NSE > MSE). In addition, activation during periods associated with the fixation-cross, which is presented between the stimuli and at the beginning and conclusion of the experiment, these time points were also examined by contrasting rest > MSE stimuli and rest > NSE. MSE > rest and NSE > rest contrasts were also examined in order to determine how activity during the two task differed from rest. These analyses produced parameter estimate maps and variance maps, which were then forwarded to a whole-head second level analysis. A covariate of no interest, gray matter volume, was also included in the model. This covariate identified cortical regions that contained variance, which could be explained by differences in gray matter volume (i.e., the motor cortex and visual areas). The final higher-level analysis resulted in three voxel-wise parameter estimate maps of interest for each condition mean. Regions of interest (ROIs) were then determined based on a Z statistic images thresh-hold map and using clusters determined by a voxel-wise threshold of $z > 2.33$ ($p < 0.01$) and a corrected cluster-wise threshold of $p < 0.05$. The significant ROIs for each contrast determined from this analysis are included in Table 3. However the primary contrasts of interest were the MSE > NSE and the rest > MSE contrasts as these were the contrasts hypothesized to best represent the self-referenced behavior during the self-efficacy task and the default network.

After extracting the activity level from the significant ROIs, the second goal of objective 1 was to determine how activity in the ROIs from the MSE > NSE contrast (i.e., retrosplenial, ACC, dMPFC, TPJ, vMPFC) were related to memory performance (i.e., proportion of correct responses and dprime) on a relational memory task (Dennis et al., 2008). It was hypothesized that activity in these ROIs would be significantly related to performance on the memory paradigm. Specifically, better memory performance (i.e., higher proportion of correct responses and *d* prime scores) would be associated with greater activation in all self-referential ROIs. To examine these relationships a correlation analysis was performed in which, life-long learning membership and education were included as covariates. In addition to investigating the relationship between the hypothesized self-referential ROIs and memory performance, any non-hypothesized ROIs that were active during the MSE > NSE contrast were included in a second set of correlations in order to establish their relationship with memory performance.

Objective 2: Relationship between physical activity, cardiorespiratory fitness, self-efficacy brain activity and memory performance

The second objective of this study was to first determine whether activity groups (i.e., high and low active), show differences in brain activity in the ROIs active during the self-reference task as determined in objective 1 (i.e., retrosplenial, ACC, dMPFC, TPJ, vMPFC from MSE > NSE contrast). The second goal of this objective was to determine how physical activity, cardiorespiratory fitness, self-efficacy and brain activity during the self-referential task influence memory performance. Based on the previous research on physical activity's effect on self-efficacy (McAuley & Blissmer, 2000; McAuley et al., 2005) and self-efficacy's relationship with cognitive function (Bandura & Wood, 1989; Serra et al., 2008; West et al., 2008), it was hypothesized that the ROIs during the self-referential task (i.e., retrosplenial, ACC, dMPFC, TPJ, vMPFC) would show greater activity for the individuals in the high active group as compared to the low active group. In addition, it was hypothesized that greater participation in physical activity, higher fitness, higher self-efficacy, and greater activity in ROIs (i.e., retrosplenial, ACC, dMPFC, TPJ, vMPFC) would be related to better memory performance (i.e., proportion of correct responses and *d* prime).

Next, in order to examine differences in brain activity for the two activity groups (i.e., high vs. low physical activity groups) all of the significant hypothesized ROIs (i.e., retrosplenial, ACC, dMPFC, TPJ, vMPFC) were included in a MANOVA. Education was included in this analysis as a covariate. In addition to determining the differences in brain activity by group for the hypothesized self-reflective ROIs, the same MANOVA procedure was repeated for all significant, non-hypothesized ROIs.

To determine the relationship between cardiorespiratory fitness, physical activity, self-efficacy, memory performance, and the self-reference ROIs, correlation analyses were initially conducted. These analyses included the all self-reference ROIs identified in objective 1 (i.e., retrosplenial, ACC, dMPFC, TPJ, vMPFC), relational memory task performance (i.e., proportion of correct trials and dprime), self-efficacy (i.e., F of F, all MCI subscales, and MSE percent), cardiorespiratory fitness, and physical activity (i.e., total and MVPA). Potential covariates, life-long learning membership and education were also included in the analysis.

Finally, to examine the independent contributions of physical activity, cardiorespiratory fitness, self-efficacy, and brain activation on memory performance a hierarchical linear regression was conducted. This analysis included physical activity, fitness, and self-efficacy and the ROIs from objective 1 (i.e., retrosplenial, ACC, dMPFC, TPJ, vMPFC) as independent variables and memory performance as the dependent variable. Education was included as a covariate in this analysis.

Chapter 4: Results

Sample Characteristics

Original Physical Activity Groups

Two age and sex matched groups of older adults were recruited and screened to participate in neuroimaging, psychosocial, physical activity and cardiorespiratory fitness testing for this study. Initially, 25 low-active adults and 26 high active-adults, aged 60 to 79 years completed all measures. However, two sedentary individuals had to be removed from the sample due to a stroke occurring sometime between the day they were screened and the day they were to complete testing. This resulted in three high-active individuals also being removed from the sample, in order to match groups by age and sex. Therefore, 23 sedentary and 23 active individuals completed all required testing and were retained for analysis. The two groups were age matched ±1 year. The sample characteristics for the two groups and the sample as a whole, including physical activity, cardiorespiratory fitness, self-efficacy and memory performance has been included in Table 1.

Based on sample characteristics alone, the two activity groups were significantly different in terms of life-long-learning program membership, body mass index (BMI), total physical activity counts per day, number of MVPA counts per day, and cardiorespiratory fitness. In all cases, the high-active participants were more likely to participate in a life-long-learning program, have a lower BMI, were more physically active, and had higher cardiorespiratory fitness. Self-efficacy and memory performance did not differ between the two groups. Reaction time (ms) during the memory self-efficacy task did not significantly differ by physical activity group or based on the type of response made (e.g., yes or no (t (45) =.290, p = .773)). For the NSE condition, the two physical activity groups also did not differ in the proportion of yes responses (i.e., I believe that it will rain) or response time (see Table 1). However, the overall mean reaction time for NSE task was significantly faster than the mean response time for the memory self-efficacy task (t (45) = -2.018, p = .05).

MVPA Groups

Based on the accelerometer data for MVPA per day, 8 self-reported high active individuals were moved to the low group while three self-reported low active individuals were moved to the high group. This resulted in two MVPA groups. The MVPA groups consisted of 28 low-active individuals and 18 high-active individuals. The sample characteristics for the two new groups and the sample as a whole, including physical activity, cardiorespiratory fitness, self-efficacy and memory performance are included in Table 2.

The MVPA sample characteristics showed that the low MVPA and high MVPA individuals were significantly different in terms of age, education, physical activity, fitness, F of F score, and reaction time for the NSE task. Specifically, the high active group was younger, had more years of eduction, participated in more physical activity, had higher cardiorespiratory fitness, higher F of F score, and had a slower reaction time during the NSE task. There was also a trend towards a significant difference in MCI potential improvement (p = .077), NSE no response reaction time (p = .068), proportion of correct response (p =.060) and d prime (p = .112), where individuals in the high active group had high confidence in their ability to improve their memory, slow NSE RT, and better memory performance than those in the low-active group.

Objective 1

Brain Regions Associated with Self-efficacy

The first objective of this study was to identify which brain regions were associated with self-efficacy during the performance of a self-referential task in the MRI and then to determine whether these ROIs were related to task performance on the relational memory task. It was hypothesized that the retrosplenial, ACC, dMPFC, TPJ, and the vMPFC (Van Overwalle, 2009; Buckner et al., 2008) would be active during the self-referential task (i.e., MSE > NSE contrast). Results supported this hypothesis, as all five brain regions were active during the self-referential task suggesting that the retroplenial, the ACC, dMPFC, TPJ, and vMPFC are all associated with self-efficacy for memory performance (see Table 3A and Figure 3A). In addition to the hypothesized ROI for the MSE > NSE contrast, several other brain areas were also significantly active. These brain regions included the left occipital cortex (OCC), left precentral gyrus (PrG), left temporal pole (TP), left superior frontal gyrus (SFG), right temporal occipital fusiform gyrus (TOF), and the right and left paracingulate gyri (PAC) (see Table 3B and Figure 3B).

It was also hypothesized that the default network would be active during the rest/ fixation periods of the self-referential task (i.e., rest > MSE and rest > NSE contrasts); however, no default network activity was observed. This finding may be due to the overlap in brain regions that are associated with both self-referential tasks and the resting state or default network. Although it was not hypothesized, several brain regions during the MSE and NSE conditions were also more active than the rest condition. During the MSE condition, the right and left occipital poles (OP), precentral gyrus (PrG), and the right and left frontal poles (FP) were more active (see Table 3C and Figure 3C). These findings confirm that reading and information processing were taking place during the MSE condition and not during rest. Similarly, the OP and FP were also active in the NSE condition (see Table 3D and Figure 2D).

Relationship Between ROIs and Memory Performance

Relationship between hypothesized ROIs and memory performance. It was hypothesized that greater activation in the retroplenial, the ACC, dMPFC, TPJ, and vMPFC would be significantly related to better memory performance (i.e., greater proportion of correct responses and higher *d* prime score). To determine the relationship between the MSE ROIs and task performance bivariate correlations were conducted (see Table 4). Although activity in the ACC was significantly related to education (r = .360, p =.014), neither education nor life-long learning membership were related to memory performance or any brain regions that were associated with it. These variables were therefore dropped from all subsequent analyses. Only activity in the dMPFC was significantly associated with memory performance. Specifically, greater deactivation in the dMPFC was significantly associated with the proportion of correct responses (r = -.292, p =.049) on the memory task. There was also a trend towards significance (r = -.259, p = .082) between *d* prime and deactivation in the dMPFC. Again, this correlation suggests that better performance on the memory task was associated with greater deactivation in the dMPFC.

Relationship between non-hypothesized ROIs and memory performance. To determine the relationship between the non-hypothesized ROIs and task performance a second set of bivariate correlations were conducted (Table 5). Results showed that brain activity in these ROIs were not significantly related to education. However, life-long learning status was significantly related to activity in the left PrG (r = .470, p = .001) and left PCC (r = .320, p = .030). Finally, none of the non-hypothesized ROIs were significantly related to memory performance.

Objective 2

Relationship Between Relational Memory Performance, Self-efficacy, Activity Group, Physical Activity, Cardiorespiratory Fitness and Brain Activity

Differences in Brain Activity by Activity Group. It was hypothesized that the ROIs for the self-efficacy task (i.e., retrosplenial cortex, ACC, dMPFC, TPJ, and vMPFC) would show greater activity for the individuals in the high active group as compared to the low active group.

Results showed no group differences for any the dependent variables, $F(5,39) = 1.492$, $p = .215$, $eta^2 = .161$ (Table 5.). A follow up MANOVA consisting of the ACC and the dMPFC, the only brain regions significantly associated with self-efficacy, confirmed that no significant differences existed between groups, $F(5,39) = 1.596$, $p = .215$, $eta^2 = .071$. However, in both analyses there was a trend towards a significant difference in brain activity for the dMPFC, $F(1,43) = 3.260$, $p = .078$, $eta^2 = .070$, suggesting that individuals in the high-active group showed deactivation in this brain region, while individuals in the low-active group showed activation. In addition, the mean differences in brain activity, by group showed a trend towards more deactivation for the high active individuals. Figure 4 and Table 6 display these group differences. In summary, these findings indicate that the two activity groups overall were not significantly different in brain activity. However, there was a trend towards individuals in the high activity group having more deactivation in the dMPFC than individuals in the low activity group. Moreover, this was a moderate effect as indicated by the eta^2.

Differences in Brain Bctivity by MVPA Group. Similar to the activity group differences in brain activity, the only brain area to show differential activity between the MVAP groups was the dMPFC, $F(1,43) = 5.629$, $p = .022$, $eta^2 = .116$. Specifically, there was greater deactivation of the dMPFC in the high MVPA group as compared to the low MVPA group (see Table 7 and Figure 5).

Differences in Brain Activity for Non-hypothesized ROIs. Differences in other brain regions that were significantly active during the MSE > NSE contrast, but were not hypothesized as being related to self-reflective thought, were also compared based on the originally established physical activity groups (1) and MVPA groups (2). Results showed that activity in the non-hypothesized brain regions did not differ by physical activity, F(7,43) = .133, p = .995, eta^2 =.08, nor based on MVPA group, F(7,43) = 1.060, p = .408, eta^2 =.167.

Relationship Between Physical Activity, Cardiorespiratory Fitness, Self-efficacy Brain Activity and Memory Performance

It was hypothesized that those individuals who are more fit and active would also have higher self-efficacy, better memory performance and greater activity in all ROIs including retroplenial, the ACC, dMPFC, TPJ, and vMPFC. To evaluate the relationship between memory task performance, self-efficacy, physical activity, and cardiorespiratory fitness, and the MSE ROIs determined in objective 1, bivariate correlations were conducted. Education and life-long-learning group membership were also included in the correlations to determine if they would be required covariates for subsequent analyses (see Table 8). The correlations showed that F of F was significantly related to the proportion of correct trials for the memory task (r =.333, p =.024), d prime (r =.336, p =.023), cardiorespiratory fitness (r =.396, p =.006), total physical activity counts (r =.328, p =.026), MVPA counts (r =.361, p =.014), activity in the ACC (r =.328, p =.026) and deactivation in dMPFC (r = -.327, p = .027). F of F was also significantly related to all other measures of self-efficacy (i.e., all MCI subscales and MSE percent). Deactivation in the dMPFC was significantly related to the proportion of correct responses on the memory task (r = -.292, p = .049) and MVPA counts per day (r = -.314, p = .034). Counter to prior findings in the literature, cardiorespiratory fitness, was not related to memory task performance, self-efficacy, or brain activity. Education was significantly related to cardiorespiratory fitness (r = .386, p = .008), total physical activity counts (r = .499, p = .000), MVPA (r = .411, p = .005) and activity in the ACC (r = .360, p = .014). Life-long-learning membership was not related to memory performance, self-efficacy, cardiorespiratory fitness, or physical activity variable and was dropped as a covariate in subsequent analyses. The correlational findings suggest that higher self-efficacy may be related to better memory task performance, activation in the ACC and deactivation in the dMPFC. Additionally, deactivation in the dMPFC was also related to greater participation MVPA.

Influence of Physical Activity, Cardiorespiratory Fitness, Self-efficacy and Brain Activation on Memory Performance. It was hypothesized that those individuals in the high activity group would be more efficacious and perform better on the memory task, and that the enhanced performance would be positively related to activation in the self-reflective ROIs. The hierarchical linear regression analysis with proportion of correct responses as the dependent variable was non-significant. Results showed that these variables together did not influence performance on the memory task (proportion of correct responses) $F(5,45) = 1.718$, $p = .153$, $R^2 = .177$ (see Table 9). The same hierarchical linear regression was conducted with *d* prime as the dependent variable and again was non-significant, $F(5,45) = 1.537$, $p = .200$, $R^2 = .161$ (see Table 10). However, in both cases, several of the independent variables did have sizable beta values suggesting that if the sample size were larger, they might be significantly associated with memory performance. Specifically, self-efficacy (i.e., F of F score), ß = .199, $p = .237$, contributed approximately 3% of the variance associated with proportion of correct responses, and 3.5% of the variation *d* prime memory performance, ß = .215, $p = .205$. Similarly, dMPFC brain deactivation, ß = -.175, $p = .276$, contributed approximately 2.5% of the variance associated with the proportion of correct responses and 1.6% of the variance associated with *d* prime, ß = -.141, $p = .383$. Together these findings suggest that both self-efficacy, and brain activity during the self-referential task may be positively impacting subsequent memory performance.

Summary of Findings

In summary, results showed that the retrosplenial, ACC, dMPFC, TPJ, and the vMPFC (Van Overwalle, 2009; Buckner et al., 2008) were all active during the self-reference task. It was also hypothesized that greater activity in these brain regions would be related to better memory performance, however results showed that greater activity in the form of deactivation, specifically in the dMPFC, was related to both the proportion of correct responses and *d* prime. Results also showed that other, non-hypothesized, brain regions including the left OCC, left PrG, left TP, left SFG, TOF, and the right and left PAC were also active during the self-reference task; however, brain activity in these regions was unrelated to memory performance.

It was also hypothesized that default network would be active during the rest periods of the cognitive task, however we were unable to investigate this hypothesis. Even so, results did show that the OP and FP were also active during the MSE and NSE task conditions (based on MSE > rest and NSE > rest contrasts), suggesting that reading and information processing were taking place during the MSE and NSE tasks, but not during the rest periods.

Although results were unable to support the hypothesis that activity group (i.e., high and low active) would show differences in brain activity in the ROIs active during the self-reference task, there was a trend towards individuals in the high activity group having more deactivation in the dMPFC than individuals in the low activity group. As hypothesized, findings showed higher self-efficacy (i.e., less F of F) was related to better performance on the memory task. In addition, higher self-efficacy was related to greater cardiorespiratory fitness and greater participation in physical activity. Finally, higher self-efficacy was related to activation in the ACC and deactivation in dMPFC. Additionally, deactivation in the dMPFC was associated with better memory task performance and greater participation in physical activity. Finally, findings showed that physical activity, cardiorespiratory fitness, self-efficacy and brain activation on memory performance together did not independently influence performance on the memory task (proportion of correct responses or *d* prime).

Chapter 5: Discussion

Brain Regions Associated with Self-Efficacy and Memory Peformance

There were two main goals for this first objective; the first was to determine which brain regions were active during the self-referential task that was designed to assess self-efficacy performance and which brain regions were active during the periods of rest between tasks. As hypothesized the retrosplenial, ACC, dMPFC, TPJ, and the vMPFC (van Overwalle, 2009; Buckner et al., 2008) were all active during the self-reference task and the OP and FP were also active, however, there were no active brain areas during the rest periods.

The second goal of this objective was to establish which of the self-reflective brain regions that were active during the task, were related to memory performance on a self-reflective memory task. It was hypothesized that all self-referential brain regions (e.g., retrosplenial, ACC, dMPFC, TPJ, and the vMPFC) would be related to memory performance, however; only activity in the dMPFC was significantly associated with performance. Specifically, deactivation in the dMPFC was associated with better memory performance.

Although the findings from this study suggest that activity in the dMPFC is related to self-referential behavior, supporting previous findings (e.g., van Overwalle, 2009), it was not hypothesized that there would be deactivation in the dMPFC during the task. A review by Gusnard and Raichle (2001) suggests that a psychological baseline for the brain’s behavior when it is awake, but at rest, should be established in fMRI and PET research. However, the manner in which brain baseline is established in the literature has been inconsistent. Many studies, the present study included, establish a brain baseline as when the brain is at rest before the experiment begins or at break points between experiment blocks. Brain activity during these short-resting periods is then taken into account during the response conditions. In other studies, participants view abstract stimuli or scrambled photos and this passive viewing task is then used as baseline. Even so, neural activity during rest periods (even short, 3 s rest periods) can reduce, eliminate, or even reverse the sign of activity during a cognitive task, therefore a consistent means of collecting data during rest needs to be established (Stark & Squire, 2001).

In addition, the findings in this study can also be related to the unique activation patterns exhibited in the dMPFC during self-referencing tasks. Specifically, McGuire and colleagues (1997) found that self-referential brain activity was always greater than rest, which was also greater than non-self-referential behavior (i.e., MSE > rest > NSE). Therefore, the fact that no rest > MSE activity was observed is not unusual. In addition, self-referential thought often occurs in between cognitive task trials or when the brain is supposedly at rest, or naturally deactivating (Gusnard & Raichle, 2001; McGuire et al., 1997). Therefore, deactivation being observed in the present study during the MSE > NSE condition is not uncommon. Even so, better control over baseline resting conditions is still needed in order to come to clear scientific conclusions.

The neural composition and connections of the dMPFC to other regions of the brain may also explain study findings. Previous research suggests that the dMPFC receives a wide range of sensory information from the body as well as the external environment via the orbital prefrontal cortex (Wall & Messier, 2001). Additionally, the dMPFC is also heavily interconnected with limbic system structures via the brainstem (Forbes & Grafman, 2010). Research has suggested that connections with these brain regions may mediate the integration of emotional and cognitive processes by incorporating emotional biasing signals or markers into decision-making processes and thought (Bechara, Damasio, & Damasio, 2000; Forbes & Grafman, 2010). This is important as such processes come into play when one self-reflects and makes decisions about behaviors or capabilities.

In addition to brain activity being observed in the hypothesized self-referential ROIs, a significant level of brain activity was also present in several other brain regions (i.e., left OCC, left PrG, left TP, left SFG, right TOC, and right and left PCC). Although activity in these ROI was not significantly related to memory performance nor was it influenced by physical activity or MVPA level, the functional reasoning for this observed brain activity is still relevant for discussion. Activity in the OCC was observed because it is part of the visual system and necessary for reading and other visual processes (Erik, Hallett, & Cowey, 2003; Kastner, Demmer, & Ziemann, 1998). Activation in the PrG, on the other hand, is motor related and required for the initiation of skeletal muscle contractions (Kwan, MacKay, Murphy, & Wong, 1978). This type of muscle movement is necessary for responding during a task. The TP is considered an extension of the limbic system and is involved in the processing of social and emotional stimuli. The TP has also been argued as necessary for facial recognition. Both of these properties are relevant to the MSE task as this task is both social/emotional in nature and required for remembering face-scene pairs (Olson, Plotzker, & Ezzyat, 2007). SFG activation was also observed during the MSE > NSE contrast. SFG is thought to contribute to higher cognitive function, including memory function, which may come into play when reflecting on one's ability to remember stimuli (du Boisgueheneuc et al., 2006). The TOC is also sensitive to the processing of faces and is referred to as the occipital face area. Therefore this brain region may have been active as the MSE task asked participants to reflect on their ability to remember face-scene pairs (Rossion et al., 2003). Finally, the PCC was also active during the MSE task. Literature regarding the PCC suggests that it is necessary for predicting the future. Moreover, it is also involved in other social and self-referential processes (Lemogne et al., 2010; Walter et al., 2004).

Findings also showed that the OP and the FP were active during both the MSE and NSE conditions as compared to the rest condition. This finding may be important in that is supports the position that reading, attending, and processing stimuli were ongoing during the task and not during the rest condition. Okuda and colleagues (2003) have also suggested that the FP is especially active when one is asked to think about future events that may or may not occur. In addition, Addis and Schacter (2008) showed greater activity in the FP when participants were asked think about future events rather than past events. In the present task, participants were asked to think about not only their future performance on the memory task, but also to think about whether or not they thought it would rain in the next month. As for OP activity, several studies using TMS have confirmed that placing a TMS magnet over the occipital pole region does disrupt vision, thus suggesting that this region is necessary for processing visual stimuli (Erik et al., 2003; Kastner et al., 1998).

Results of this study also suggest that better memory task performance is related to deactivation in the dMPFC, findings that are also supported by previous research. Zhu and colleagues (2011) found that the dMPFC is heavily involved in memory performance and self-referencing behavior when completing a task that involved both types of components. Specifically, Zhu et al. found that dMPFC activity later predicted memory performance even for non self-referencing stimuli. In the present study, we also found that greater deactivation in the dMPFC was related to better memory performance. Other researchers have also reported that greater deactivation in the dMPFC is related to better memory performance (Sambataro et al., 2010). Specifically, Sambataro (2010) found that individuals with greater dMPFC deactivation, while at rest, performed better on a 2-back task assessing working memory. This suggests that individuals with greater deactivation in the dMPFC may also have better cognitive control abilities and are therefore able to suppress interfering information more effectively which in turn leads to better task performance (Sambataro et al., 2010; Zhu et al., 2011). Our findings also support this position.

Activity Group Differences in Brain Activity

Brain activation differences by activity and MVPA groups. For the second objective we determined (a) whether high and low physical activity groups differed in brain activity in the ROIs associated with self-efficacy and (b) how physical activity, cardiorespiratory fitness, self-efficacy, and brain activity in the ROIs during the self-efficacy task independently influenced memory performance. Results of the first goal showed that the two activity groups did not significantly differ in brain activity, however, there was a trend towards individuals in the high activity group having more deactivation in the dMPFC than individuals in the low activity group.

Although the relationship between physical activity group or MVPA group and brain activity was not significant, the trend suggest that activation in the dMPFC does significantly differ based on physical activity group, whereby individuals in the high active group show patterns of deactivation and individuals in the low active group show patterns of activation in this brain region. However, it is not clear if physical activity or cardiorespirpatory fitness influenced this relationship. Findings by Voss and colleagues (2010) suggest that participating in a physical activity intervention, to increase cardiorespiratory fitness, is associated with changes in default network or resting state brain connections, specifically within the prefrontal cortex. As deactivation was observed in the dMPFC, the current study also provides support that participating in physical activity may be important for not only resting brain activity, but also brain health in general.

Relationship Between Physical Activity, Cardiorespiratory Fitness, Self-Efficacy Brain Activity and Memory Performance

Initial correlation analyses showed higher self-efficacy was related to better memory task performance, to greater cardiorespiratory fitness, greater participation in physical activity and to activation in the ACC and deactivation in dMPFC. Results also showed that deactivation in the dMPFC was associated with better memory task performance and greater participation in physical activity. Findings from a regression analysis showed that physical activity, cardiorespiratory fitness, self-efficacy and brain activation together did not influence performance on the memory task (proportion of correct responses or *d* prime).

Although the correlations and regression findings do not suggest that physical activity, cardiorespiratory fitness, self-efficacy, and brain activity may have a significant influence on memory performance. Previous research conducted by Szabo et al. (2011) did find a significant relationship between cardiorespiratory fitness, hippocampal volume, memory performance, and F of F in older adults. This difference in findings could be related to the difference in the type of relational memory task used to investigate memory performance. In Szabo et al's study, a spatial relational memory task was used, while in the current study participants completed a face-scene relational memory paradigm. In addition, Erickson and colleagues (2009) has also reported a significant relationship between spatial relational memory and cardiorespiratory fitness. Erickson et al. found that individuals with higher levels of fitness not only performed better on a spatial relational memory task, but this relationship was also mediated by hippocampal volume. Together Szabo et al. (2011) and Erickson et al.'s (2009) findings suggest that relational memory should be related to cardiorespiratory fitness. Even so, other longitudinal randomized control trial findings by Erickson et al. (2011) have indicated that this may not be the case. Specifically, Erickson et al. (2011) found that although cardiorespiratory fitness and hippocampal volume increase in a group of older adults participating in a year-long aerobic exercise intervention, these changes were not associated with significant improvements in spatial relational memory performance. Similarly, those individuals who participated in a stretching and strengthening control group, who did not experience significant increases in fitness or hippocampal volume, did not show memory performance declines. Therefore, It is possible that relational memory performance is relatively stable as compared to other cognitive functions (i.e., executive function), which are consistently shown to be influenced by participating in physical activity to increase cardiorespiratory fitness (Colcombe et al., 2006; Colcombe & Kramer, 2003; Kramer et al., 1999).

Unlike the present study, previous research using similar relational memory paradigms has shown a significant relationship exists between cardiorespiratory fitness and memory performance, however, all of this research has been conducted in children (Chaddock et al., 2010; Chaddock, Hillman, Buck, & Cohen, 2011; Monti, Hillman, & Cohen, 2012). Specifically, Chaddock et al. (2010) found that higher-fit children have greater hippocampal volume and superior relational memory task performance than lower-fit children and that the relationship between fitness and memory performance is mediated by hippocampus volume. Monti and colleagues (2012) also found that when aerobic fitness is increased, by participating in an exercise intervention, relational memory performance increased as well. Together these findings indicate that fitness is associated with relational memory performance in children. However, the same has not been found for older adults. Thus, the findings from the present study and previous studies (Szabo et al., 2010) suggest that the fitness, physical activity and memory relationship be only present for specific types of memory (i.e., spatial and not relational) as aging may adversely effect some types of memory more than others (i.e., spatial and not relational). Yet, more research is required to examine this relationship.

Previous research also suggests that cognitive performance and self-efficacy are both significantly related to brain activity such as ERN and Pe amplitudes. Specifically, Themanson et al. (2011) found that ERN amplitude mediated the relationship between SE and post-error response accuracy in a flanker task in which response accuracy was stressed in the instructions. These findings suggest that brain activity is not only related to cognitive task performance, but self-efficacy. Thus, the findings by Themanson and colleagues (2011), combined with Szabo et al (2011) suggest that there is a relationship between self-efficacy, cardiorespiratory fitness, physical activity, memory performance, and brain activation, and although the present study was designed to more clearly define the relationships between these variables, the small sample size has allowed for limited conclusions.

Although a majority of the literature on aging, cognitive function and exercise would support a significant relationship between cardiorespiratory fitness and cognitive function (Colcombe & Kramer, 2003; Erickson et al., 2011; Erickson et al., 2009; Kramer et al., 1999), we did not find results to support this claim. The correlation findings suggest that physical activity participation (both total and MVPA per day) is more strongly related to memory performance than physical fitness. Other researchers have also found similar results. Ruscheweyh and colleagues (2011), for example, found physical activity based on changes in energy expenditure, rather than changes in fitness, from participating in a six-month exercise intervention resulted in significant changes in physical activity (kcal/week) that were related to improvements in episodic memory recall and increases in brain volume. Flöel et al. (2010) also found that physical activity participation was significantly associated with gray matter volume, which in turn was also related to memory performance, however, physical fitness was not related to either variable. Together with the present study's correlations, these findings suggest that physical activity participation both cross-sectionally and within the context of an intervention may be more strongly related to memory performance. However, more studies assessing both physical activity and cardiorespiratory fitness are needed before a definitive conclusion can be made.

Self-Referencing Tasks, Self-Regulation, and Health Behavior

Although this is the first study to investigate the relationship between self-efficacy, brain activity, and health behaviors such as physical activity, results were able to show that those regions previously related to self-referencing behaviors are also related to self-efficacy. In addition to the literature supporting the role of the dMPFC within the context of self-referencing thoughts, such brain regions have also been shown to be important for self-regulation, especially when it comes to weight management and eating behaviors. Previous research suggests that the prefrontal cortex, including the dMPFC, is not only a critical brain region for homeostatic, reward, and self-referencing cognitions, but is also a mediator of appetite. Additionally, the MPFC seems to be exceptionally active when subjects exercise self-control, or attempts to self-regulate their food decisions (Hare, Camerer, & Rangel, 2009). The neural circuits in this region have also more generally been associated with executive functions, including memory (Fuster, 2008; Miller & Cummings, 2007), whereby lesions in this brain region are not only related to poor executive function, but also the inability to self-regulate. Thus, the MPFC is also necessary for maintaining and monitoring eating-related goals during food consumption, modulating reward and satiation, and ultimately cognitively controlling food intake (Alonso-Alonso, 2010). However, the regulatory influence of the dMPFC may not be only specific to food.

Even though much of the previous research involving the dMPFC as a behavioral regulator is based on eating behaviors, previous research conducted by McAuley et al. (2011) may also provide support for the dMPFC's involvement in maintaining health behaviors like physical activity. This is because physical activity participation is also extremely difficult to manage and success requires one to be able to effectively self-regulate. McAuley and colleagues (2011) suggest that integrating the social/psychological and neurocognitive definitions of self-regulation through social cognitive theory can provide an effective model for explaining how one maintains positive health behaviors such as physical activity. Specifically, these researchers suggest that the maintenance of health behaviors, in this case physical activity is determined by one's cognitive abilities and self-regulatory capabilities. This relationship is mediated by self-efficacy, which was found to influence adherence to a year-long exercise intervention. Therefore, if self-efficacy is important for self-regulating physical activity and the dMPFC is important for self-regulating eating behaviors one may suggest that the activity in the dMPFC may also be related to the maintenance of physical activity over time. However, this position warrants empirical testing.

General Study Strengths and Limitations

This study is the first to investigate the relationship between brain activity associated with self-referencing behaviors, physical activity, cardiorespiratory fitness, and memory performance in older adults. This study was successful in showing that those regions thought to relate to self-referencing behaviors are also related to self-efficacy. However, as with any study, there are a number of limitations that should be acknowledged. This study was limited in sample size and although many of the findings were in the hypothesized direction strong conclusions were unable to be made. Regardless, this study adds to the literature, by suggesting that self-reflective brain regions, such as the dMPFC are related to self-referential behavior as well as subsequent memory performance. In addition these findings also validate previous study findings that self-efficacy is related to memory performance as well as physical activity and cardiorespiratory fitness.

Another limitation of the current task is that it did not allow for the investigation of differences in brain activity based on yes or no response type during the MSE task condition. This was due to there being only 24 trials of the MSE task and although response rates were high (approximately 95%), self-efficacy for the memory task was low (42%), leaving less than 12 trials of yes and 12 trials of no responses for comparison. This in turn did not provide enough power to perform a comparison of yes vs. no brain activity difference. Future self-referencing/self-efficacy paradigms should include more trials as fMRI scanning time allows.

Finally, the present investigation was cross-sectional in nature and therefore it does not provide any insight as to how changes in physical activity behavior or cardioresiratory fitness can influence both brain activity in the dMPFC or self-efficacy. Both changes in brain activity and self-efficacy relative to changes in physical activity and cardiorespiratory fitness should be investigated longitudinally, as well as within the context of an exercise intervention. This should allow researchers to determine how changes in physical activity and fitness constructs impact self-efficacy for cognitive function and self-referencing brain regions such as the dMPFC.

Future Recommendations

These data do provide support for using fMRI to examine the active brain regions associated with self-efficacy and their relationship with performance on a memory task. In addition, this study also provides initial support that brain activity during a self-referential task may differ based on physical activity group status, and that participating in physical activity and having higher cardiorespiratory fitness may influence self-efficacy cognitions. However, future studies should first attempt to replicate these findings first with a larger sample size and second longitudinally to determine relationships among changes in these constructs across time.

Future research should also be conducted to attempt to better understand what moderates/ mediates the group differences in brain activity and self-efficacy as well as how such factors induce changes in self-efficacy for cognitive performance (i.e., changes in physical activity or fitness). Both questions were unable to be answered by the current study.

In addition, to better determine the role of physical activity and fitness in brain function relative to self-efficacy, future research on self-efficacy and self-referential thought in general should be conducted using a task design consisting of more trials. This type of research would not only help to more clearly identify the brain regions associated with self-efficacy, but would also help to define conclusions relative to how these brain regions influence subsequent cognitive performance. Additionally, more trials would also provide insight as to whether or not brain activity is different in those individuals who are highly efficacious as compared to those who are not (i.e., difference is brain activity for yes and no responses). Further, different varieties of self-efficacy tasks should be developed to determine if the brain regions active during the self-efficacy task are only related to memory performance on a relational memory paradigm or if such brain regions are also active when assessing self-efficacy for other executive function task.

Findings from this study suggest that self-efficacy and the brain regions associated with self-efficacy cognition are related to memory performance. Although, not conclusive, physical activity and cardiorespiratory fitness were also related to self-efficacy and the brain regions active during a self-referential task indicating that these variable may also be important for cognitive function as well. Although this research is in its infancy, there is some support for self-efficacy's potential as an important factor in brain health and the maintenance of cognition.

Conclusions

In conclusion, these data provide initial evidence that ROIs associated with self-referential tasks (i.e., retrosplenial cortex, ACC, dMPFC, TPJ, and vMPFC) are active during a task developed to assess self-efficacy. Also, these ROIs are significantly related to performance on a relational memory paradigm. Specifically, better memory performance (i.e., greater proportion of correct responses and *d* prime score) was associated with greater activation in the dMPFC. This study also provides evidence that participating in more physical activity (i.e., based on physical activity and MVPA groups) is associated with greater deactivation in the dMPFC during a self-efficacy task. Also, evidence suggested that deactivation in the dMPFC is associated with better memory task performance. Although there was limited evidence to suggest that relational memory performance is associated with physical activity or fitness, additional research is need to clearly define this relationship as aging seems to more adversely influence certain types of memory more than others. Together, these findings provide an initial understanding about the relationship between self-efficacy and the brain regions associated with it, as well as how participating in more physical activity, may positively impact brain activity within its associated regions. However, more research is needed before strong conclusions can be made. Regardless, this study does provide an initial stepping stone to establish how self-efficacy and its associated brain regions are related to brain health and cognitive function in older adults.

Chapter 6: References

Addis, D. R., & Schacter, D. L. (2008). Constructive episodic simulation: Temporal distance and detail of past and future events modulate hippocampal engagement. *Hippocampus, 18,* 227-237. doi: 10.1002/hipo.20405

Angevaren, M., Aufdemkampe, G., Verhaar, H. J., Aleman, A., & Vanhees, L. (2008). Physical activity and enhanced fitness to improve cognitive function in older people without cognitive impairment. *Cohrane Database Systematic Reviews*, *16*(3). doi: 10.1002/14651858.CD005381.pub3

Annesi, J. J., & Unruh, J. L. (2008). Relations of exercise, self-appraisal, mood changes and weight loss in obese women: testing propositions based on Baker and Brownell's (2000) model. *American Journal of Medical Science*, *335*(3), 198-204. doi: 10.1097/MAJ.0b013e318152010c00000441-200803000-00005 [pii]

Balke, B., & Ware, R. W. (1959). An experimental study of physical fitness of Air Force personnel. *United States Armed Forces Medical Journal*, *10*(6), 675.

Balota, D. A., Dolan, P. O., & Ducheck, J. M. (2000). Memory changes in healthy older adults. In E. Tulving & F. I. M. Craiks (Eds.), *The Oxford Handbook of Memory* (pp. 395-409). New York: Oxford University Press.

Bandura, A. (1977). Self-efficacy- Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191-215.

Bandura, A. (1986). *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. (1989). Human agency in social cognitive theory. *American Psychologist, 44*(9), 1175-1184.

Bandura, A. (1997). The anatomy of stages of change. *American Journal of Health Promotion, 12*(1), 8-10.

Bandura, A. (2004). Health promotion by social cognitive means. *Health Education & Behavior, 31*(2), 143-164. doi: 10.1177/1090198104263660

Bandura, A., & Wood, R. (1989). Effect of perceived controllability and performance standards on self-regulation of complex decision-making. *Journal of Personality and Social Psychology, 56*(5), 805-814.

Barnes, C. A., & McNaughton, B. L. (1985). An age comparison of the rates of acquisition and forgetting of spatial information in relation to long-term enhancement of hippocampal synapses. *Behavioral Neuroscience, 99*(6), 1040-1048. doi: 10.1037/0735-7044.99.6.1040

Barnes, C. A., Nadel, L., & Honig, W. K. (1980). Spatial memory deficits in senescent rats *Canadian Journal of Psychology, 34*, 29-39.

Barnes, D., Yaffe, K., Satariano, W., & Tager, I. (2003). A longitudinal study of cardiorespiratory fitness and cognitive function in healthy older adults. *Journal of American Geriatrics Society, 51*(4), 459-465.

Bassett, D. R. J., Ainsworth, B. E., Swartz, A. M., Strath, S. J., O'Brien, W. L., & King, G. A. (2000). Validity of four motion sensors in measuring moderate intensity physical activity. *Medicine & Science in Sports & Exercise, 32*, S471-S480.

Bayer-Carter, J. L., Green, P. S., Montine, T. J., VanFossen, B., Baker, L. D., Watson, S., . . . Craft, S. (2001). Diet intervention and cerebrospinal fluid biomarkers in amnestic mild cognitive impairment. *Archives of Neurology, 68*(6), 743-752.

Bechara, A., Damasio, H., & Damasio, A. R. (2000). Emotion, decision making and the orbitofrontal cortex. *Cerebral Cortex, 10*(3), 295-307.

Beck, H., Goussakov, I. V., Lie, A., Helmstaedter, C., & Elger, C. E. (2000). Synaptic plasticity in the human dentate gyrus. *Journal of Neuroscience*, *20*, 7080-7086.

Bixby, W., Spalding, T., Haufler, A., Deeny, S., Mahlow, P., & Zimmerman, J. (2007). The unique relation of physcial activity to executive function in older men and women. *Medicine & Science in Sports & Exercise*, 1408-1416.

Black, J. E., Isaacs, K. R., Anderson, B. J., Alcantara, A. A., & Greenough, W. T. (1990). Learning causes synaptogenesis, whereas motor activity causes angiogenesis, in cerebellar cortex of adult rats. *Proceedings of the National Acadeny of Sciences, 87*, 5568-5572.

Blakemore, S. J., Winston, J., & Frith, U. (2004). Social cognitive neuroscience: Where are we heading? *Trends in Cognitive Science*, *8*(5), 216-222.

Bock, B. C., Marcus, B. H., Pinto, B. M., & Forsyth, L. H. (2001). Maintenance of physical activity following an individualized motivationally tailored intervention. *Annals of Behavioral Medicine*, *23*(2), 79-87.

Brandt, J., Spencer, M., & Folstein, M. (1988). The telephone interview for cognitive status. *Neuropsychiatry Neuropsychology &Behavioral Neurology, 1*(2), 111-117.

Bray, M. S., Hagberg, J. M., Perusse, L., Rankinen, T., Roth, S. M., Wolfarth, B., & Bouchard, C. (2009). The human gene map for performance and health-related fitness phenotypes: The 2006-2007 update. *Medicine & Science in Sports & Exercise, 41*(1), 35-73. doi: 10.1249/MSS.0b013e3181844179

Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain's default network anatomy, function, and relevance to disease. *Annals of the New York Academy of Science, 1124*, 1-38. doi: 10.1196/annals.1440.011

Butler, M., & Senior, C. (2007). Towards an organizational cognitive neuroscience. *Annals of the New York Academy of Sciences, 1118*, 1-17. doi: 10.1196/annals.1412.009

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Publich Health Report, 100*(2), 126-131.

Chaddock, L., Erickson, K. I., Prakash, R., Kim, J. S., Voss, M., VanPatter, M., . . . Kramer, A. (2010). A neuroimaging investigation of the association between aerobic fitness, hippocampal volume, and memory performance in preadolescent children. *Brain Research, 1358*, 172-183. doi: 10.1016/j.brainres.2010.08.049

Chaddock, L., Hillman, C. H., Buck, S. M., & Cohen, N. J. (2011). Aerobic fitness and executive control of relational memory in preadolescent children. *Medicine & Science in Sports & Exercise, 43*(2), 344-349. doi: 10.1249/MSS.0b013e3181e9af48

Chang, M., Jonsson, P. V., Snaedal, J., Bjornsson, S., Saczynski, J. S., Aspelund, T., . . . Launer, L. J. (2010). The effect of midlife physical activity on cognitive function among older adults: AGES-Reykjavik Study. *Journal of Gerontology A Biological Sciences and Medical Sciences, 65A*(12), 1369+1374. doi: 10.1093/gerona/glq152

Chang, Y., Nien, Y., Tsai, C., & Etnier, J. L. (2010). Physical activity and cognition in older adults: The potential of Tai Chi Chuan. *Journal of Aging and Physical Activity, 18*, 451-472.

Chen, W. R., Lee, S., Kato, K., Spencer, D. D., Shepherd, G. M., & Williamson, A. (1996). Long-term modifications of synaptic efficacy in the human inferior and middle temporal cortex. *Proceedings of the National Academy of Science, 93*, 8011-8015.

Clapp, W. C., Kirk, I. J., Hamm, J. P., Shepherd, D., & Teyler, T. J. (2005). Induction of LTP in the human auditory cortex by sensory stimulation *European Journal of Neuroscience, 22*, 1135-1140.

Cohen, N. J., Ryan, J., Hunt, C., Romine, L., Wszalek, T., & Nash, C. (1999). Hippocampal system and declarative (relational) memory: Summarizing the data from functional neuroimaging studies. *Hippocampus, 9*, 83-98.

Colcombe, S., Erickson, K. I., Scalf, P. E., Kim, J. S., Prakash, R., McAuley, E., . . . Kramer, A. F. (2006). Aerobic exercise training increases brain volume in aging humans. *Journals of Gerontology Series a-Biological Sciences and Medical Sciences, 61*(11), 1166-1170.

Colcombe, S., & Kramer, A. F. (2003). Fitness effects on the cognitve function of older adults: A meta-analytic study. *Psychological Science, 14*(2), 125-130.

Colcombe, S., Kramer, A. F., McAuley, E., Erickson, K. I., & Scalf, P. (2004). Cardiovascular fitness training and changes in brain volume as measured by voxel-based morphometry. *Psychophysiology, 41*, S19-S19.

Collingridge, G. L., Kehl, S. J., & McLennan, H. (1983). Excitatory amino acids in synaptic transmission in the Schaffer collateral-commissural pathway of the rat hippocampus. *The Journal of Physiology*, *334*, 33-46.

Conn, V. S., Burks, K. J., Pomeroy, S. H., Ulbrich, S. L., & Cochran, J. E. (2003). Older women and exercise: Explanatory concepts. *Women's Health Issues, 13*(4), 158-166. doi: 10.1016/s1049-3867(03)00037-9

Cooke, S. F., & Bliss, T. V. P. (2006). Plasticity in the human central nervous system. *Brain 129*, 1659-1673. doi: 10.1093/brain/aw1082

Copeland, J. L. (2009). Accelerometer assessment of physical activity in active, healthy older adults. *Journal of Aging and Physical Activity, 17*, 17-30.

Courchesne, E., Chisum, H. J., Townsend, J., Cowles, A., Covington, J., Egaas, B., . . . Press, G. A. (2000). Normal brain developement and aging: quantitative analysis in vivo MR imaging in healthy volunteers. *Radiology, 216*, 672-682.

Craft, L. L., & Landers, D. M. (1998). The effect of exercise on clinical depression and depression resulting from mental illness: A meta-analysis. *Journal of Sport & Exercise Psychology*, *20*(4), 339-357.

D'Alonzo, K. T., Stevenson, J. S., & Davis, S. E. (2004). Outcomes of a program to enhance exercise self-efficacy and improve fitness in black and hispanic college-age women. *Research in Nursing & Health, 27*(5), 357-369. doi: 10.1002/nur.20029

Dallow, C. B., & Anderson, J. (2003). Using self-efficacy and a transtheoretical model to develop a physical activity intervention for obese women. *American Journal of Health Promotion, 17*(6), 373-381.

Daselaar, S. M., Fleck, M. S., Dobbins, I. G., Madden, D. J., & Cabeza, R. (2006). Effects of healthy aging on hippocampal and rhinal memory functions: An event-related fMRI study. *Cerebral Cortex, 16*(12), 1771-1782. doi: 10.1093/cercor/bhj112

Davachi, L., & Wagner, A. D. (2002). Hippocampal contributions to episodic encoding: Insights from relational and item-based learning. *Journal of Neurophysiology, 88*(2), 982-990. doi: 10.1152/jn00046.2002 de Jager, C. A., Budge, M. M., & Clark, R. (2003). Utility of TICS-M for the assessment of cognitive function in older adults. *International Journal of Geriatric Psychiatry, 18*, 318-324. doi: 10.1002/gps.830

Dennis, N. A., Hayes, S. M., Prince, S. E., Madden, D. J., Huettel, S. A., & Cabeza, R. (2008). Effects of aging on the neural correlates of successful item and source memory encoding. *Journal of Experimental Psychology-Learning Memory and Cognition, 34*(4), 791-808. doi: 10.1037/0278-7393.34.4.791

du Boisgueheneuc, F., Levy, R., Volle, E., Seassau, M., Duffau, H., Kinkingnehun, S., . . . Dubois, B. (2006). Functions of the left superior frontal gyrus in humans: a lesion study. *Brain, 129*, 3315-3328. doi: 10./1093/brain/awl244

Dustman, R., Ruhling, R., Russell, E., Shearer, D., Bonekat, H., Shigeoka, J., et al. (1984). Aerobic exercise training and improved neuropsychological function of older individuals. *Neurobiology of Aging, 5*, 35-42.

Ebner, N., Riediger, M., & Lindenberger, U. (2008). Faces: A database of emotional facial expressions in young, middle-aged and older women and men. *International Journal of Psychology, 43*(3-4), 783-783.

Eggermont, L. H. P., Milberg, W. P., Lipzitz, L. A., Scherder, E. J. A., & Leveille, S. G. (2009). Physical activity and executive funtion in aging: The MOBILIZE Boston Study. *Journal of American Geriatrics Society, 57*, 1750-1756. doi: 10.1111/j.1532-5415.2009.02441.x

Eldridge, L. L., Knowlton, B. T., Furmanski, C. S., Bookheimer, S. Y., & Engel, S. A. (2000). Remembering episodes: Aselective role for the hippocampus during retrieval. *Nature Neuroscience, 3*(11), 1149-1152.

Erickson, K., Voss, M. W., Parkash, R. S., Basak, C., Szabo, A. N., Chaddock, L., . . . Kramer, A. F. (2011). Exercise training increases size of the hippocampus and improves memory. *Proceedings of the National Academy of Science*.

Erickson, K. I., Prakash, R. S., Voss, M. W., Chaddock, L., Hu, L., Morris, K. S., . . . Kramer, A. F. (2009). Aerobic fitness is associated with hippocampal volume in elderly humans. *Hippocampus, 19*(10), 1030-1039. doi: 10.1002/hipo.20547

Erik, C., Hallett, M., & Cowey, A. (2003). Interference with vision by TMS over the occipital pole: A fourth period. *NeurReport, 14*(4), 651-655.

Eskes, G. A., Longman, S., Brown, A. D., McMorris, C. A., Langdon, K. D., Hogan, D. B., & Poulin, M. (2010). Conribution of physical fitness, cerebrovascular reserve and cognitive stimulation on cognitive function in post-menopausal women. *Frontiers in Aging Neuroscience, 13*(2). doi: 10.3389/fnagi.2010.00137.

Esser, S. K., Huber, R., Massimini, M., Peterson, M. J., Ferrarelli, F., & Tononi, G. (2006). A direct demonstration of cortical LTP in humans: A combined TMS/EEG study. *Brain Research Bulletin, 69*(1), 86-94. doi: 10.1016/j.brainresbull.2005.11.003

Etnier, J. L., Nowell, P. M., Landers, D. M., & Sibley, B. A. (2006). A meta-regression to examine the relationship between aerobic fitness and cognitive performance. *Brain Research Reviews, 52*(1), 119-130. doi: 10.1016/j.brainresrev.2006.01.002

Flöel, A., Ruscheweyh, R., Kruger, K., Willemer, C., Winter, B., Völker, K., . . . Knecht, S. (2010). Physical activity and memory functions: Are neurotrophins and cerebral gray matter volume the missing link? *NeuroImage, 49*(3), 2756-2763. doi: 10.1016/j.neuroimage.2009.10.043

Focht, B. C., Sanders, W. M., Brubaker, P. H., & Rejeski, W. J. (2003). Initial validation of the CSA activity monitor during rehabilitative exercise among older adults with chronic disease. *Journal of Aging and Physical Activity, 11*, 293-304.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). 'Mini-Mental State'. A practical method for grading the cognitive state of patients for the clinician. *Journal Psychiatric Research, 12*(3), 189–198.

Forbes, C. E., & Grafman, J. (2010). The role of the human prefrontal cortex in socail cognition and moral judgement. *Annual Reviews of Neuroscience, 33*, 299-324. doi: 10.1146/annurev-neuro-060909-153230

Fuster, J. (2008). *The Prefrontal Cortex*. London: Academic Press-Elsevier.

Gazzaley, A., Cooney, J. W., Rissman, J., & D'Esposito, M. (2005). Top-down suppression deficit underlies working memory impairment in normal aging. *Nature Neuroscience, 8*(12), 1791-1791. doi: 10.1038/nn1205-1791c

Ge, Y., Grossman, R. I., Babb, J. S., Rabin, M. L., Mannon, L. J., & Kolson, D. L. (2002). Age-related total gray matter and white matter changes in normal adult brain. Part I: Volumetric MR imaging analysis. *American Journal of Neuroradiology, 23*(8), 1327-1333.

Gillum, R. F., & Obisesan, T. O. (2010). Physical activity, cognitive function, and mortality in a US national cohort. *Annals of Epidemiology 20*(4), 251-257. doi: 10.1016/j.annepidem.2010.01.005

Giovanello, K., Schnyer, D. M., & Verfaellie, M. (2004). Critical role for the anterior hippocampus in relational memory: Evidence from a fMRI study comparing associative and item recognition. *Hippocampus, 14*(1), 5-8.

Gogtay, N., Giedd, J. N., Lusk, L., Hayashi, K. M., Greemstein, D., Vaituzuis, A. C., . . . Thompson, P. M. (2004). Dynamic mapping of human cortical development during childhood through early adulthood. *Proceedings of the National Acadeny of Sciences, 101*(21), 8174-8179. doi: 10.1073/pnas.0402680101

Gould, E., Reeves, A. J., Graziano, M. S. A., & Gross, C. G. (1999). Neurogenesis in the neocortex of adult primates. *Science, 286*(5439), 548-552. doi: 10.1126/science.286.5439.548

Greenough, W. T., & Volkmar, F. R. (1973). Pattern of dendritic branching in occipital cortex of rats reared in complex environments. *Experimental Neurology, 40*(2), 491-504. doi: 10.1016/0014-4886(73)90090-3

Gusnard, D. A., & Raichle, M. E. (2001). Searching for a baseline: Functional imaging and the resting human brain. *Nature Reviews Neuroscience, 2*, 685-694. doi: 10.1038/35094500

Hall, K. S., Sloane, R., Pieper, C. F., Peterson, M. J., Crowley, G. M., Cowper, P. A., . . . Morey, M. C. (2011). Long-term changes in physical activity following a one-year home-based physical activity counseling program in older adults with multiple morbidities. *Journal of Aging Research*. doi: 10.4061/2011/308407

Hampton, A. N., & O'Doherty, J. P. (2007). Decoding the neural substrates of reward-related decision making with functional MRI. *Proceedings of the National Academy of Sciences of the United States of America, 104*(4), 1377-1382. doi: 10.1073/pnas.0606297104

Hare, T. A., Camerer, C. F., & Rangel, A. (2009). Self-control in decision-making involves modulation of the vmPFC valuation systems. *Science, 324*, 646-648. doi: 10.1126/science.1168450

Harris, T. J., Owen, C. G., Victor, C. R., Adams, R., & Cook, D. G. (2009). What factors are associated with physical activity in older people, assessed objectively by accelerometry? *British Journal of Sports Medicine, 43*, 442-450.

Hendelman, D., Miller, K., Baggett, C., Debold, E., & Freedson, P. (2000). Validity of accelerometry for the assessment of moderate intensity physical activity in the field. *Medicine & Science in Sports & Exercise, 32*, S442-S449.

Hillman, B. G., Gupta, S. C., Stairs, D. J., Buonanno, A., & Dravid, S. M. (2011). Behavioral analysis of NR2C knockout mouse reveals deficit in acquisition of conditioned fear and working memory. *Neurobiology of Learning and Memroy*. doi: 10.1016/j.nlm.2011.01.008

Huang, S.-J., Hung, W.-C., Chang, M., & Chang, J. (2009). The effect of an internet-based, stage-matched message intervention on young taiwanese women's physical activity. *Journal of Health Communication, 14*(3), 210-227.

Huang, Y. Y., & Kandel, E. R. (1994). Recruitment of long-lasting and protein kinase A-dependent long-term potentiation in the CA1 region of hippocampus requires repeated tetanization. *Learning & Memory, 1*, 74-82. doi: 10.1101/lm.1.1.74

Hughes, S. L., Seymour, R. B., Campbell, R., Pollak, N., Huber, G., & Sharma, L. (2004). Impact of the fit and strong intervention on older adults with osteoarthritis. *Gerontologist, 44*(2), 217-228.

Ito, M. (2001). Cerebellar long-term depression: Characterization, signal transduction, andfunctional roles. *Psychological Reviews, 81*(3), 1143-1195.

Jenkinson, M. (2003). A fast, automated, n-dimensional phase unwarping algorithm. *Magn. Reson. Med., 49*(1), 193-197.

Jette, A. M. (2006). Toward a common language for function, disability, and health. *Physical Therapy, 86*(5), 726-734.

Kang, H., & Schuman, E. M. (1996). A requirement for local protein synthesis in neurotrophin-induced hippocampal synaptic plasticity. *Science, 273*(5280), 1402-1406. doi: 10.1126/science.273.5280.1402

Kastner, S., Demmer, I., & Ziemann, U. (1998). Transient visual field defects induced by transcranial magnetic stimulation over human occipital pole. *Experimental Brain Research, 118*(1), 19-26. doi: 10.1007/s002210050251

Katula, J. A., Rejeski, W. J., & Marsh, A. P. (2008). Enhancing quality of life in older adults: A comparison of muscular strength and power training. *Health and Quality of Life Outcomes, 6*(1), 45.

Katula, J. A., Sipe, M., Rejeski, W. J., & Focht, B. C. (2006). Strength training in older adults: An empowering intervention. *Medicine & Science in Sports & Exercise, 38*(1), 106-111. doi: 10.1249/01.mss.0000183373.95206.2f

Khaw, K. T. (1997). Epidemiological aspects of aging. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, *352*(1363), 1829-1835.

Klusmann, V., Evers, A., Schwarzer, R., Schlattmann, P., Reischies, F. M., Heuser, I., & Dimeo, F. C. (2010). Complex mental and physical activity in older women and cognitive performance: A 6-month randomized controlled trial. *Journal of Gerontology A Biological Sciences and Medical Sciences, 65*(6), 680-688. doi: 10.1093/gerona/glq053

Konkel, A., & Cohen, N. J. (2009). Relational memory and the hippocampus: Representations and methods. *Frontiers in Neuroscience, 3*(2), 166-174. doi: 10.3389/neuro.01.023.2009

Konkel, A., Warren, D. E., Duff, M. C., Tranel, D. N., & Cohen, N. J. (2008). Hippocampal amnesia impairs all manner of relational memory. *Frontiers in Human Neuroscience, 2*, 1-15. doi: 10.3389/neuro.09.015.2008

Konopack, J. E., Marquez, D. X., Hu, L., Elavsky, S., McAuley, E., & Kramer, A. F. (2008). Correlates of functional fitness in older adults. *International Journal of Behavioral Medicine, 15*(4), 311-318. doi: 10.1080/10705500802365557

Kramer, A. F., Hahn, S., Cohen, N. J., Banich, M. T., McAuley, E., Harrison, C. R., . . . Colcombe, A. (1999). Ageing, fitness and neurocognitive function. *Nature*, *400*(6743), 418-419.

Kwan, H. C., MacKay, W. A., Murphy, J. T., & Wong, Y. C. (1978). Spatial organization of precentral cortex in awake primates. II. Motor outputs. *Journal of Neurophysiology, 41*, 1120-1131.

Lachman, M. E., Bandura, M., Weaver, S. L., & Elliot, E. (1995). Assessing memory control beliefs: The memory controllability inventory. *Aging and Cognition, 2*, 67-84.

Lachman, M. E., Weaver, S. L., Bandura, M., Elliot, E., & Lewkowicz, C. J. (1992). Improving memory and control beliefs through cognitive restructuring and self-generated strategies. *Journal of Gerontology, 47*, 293-299.

Lemogne, C., Gorwood, P., Bergouignan, L., Pelissolo, A., Lehericy, S., & Fossati, P. (2010). Negative affectivity, self-referential processing and the cortical midline structures. *Social Cognitive and Affective Neuroscience*. doi: 10.1093/scan/nsq049

Li, F., McAuley, E., Fisher, K. J., Harmer, P., Chaumeton, N., & Wilson, N. L. (2002). Self-efficacy as a mediator between fear of falling and functional ability in the elderly. *Journal of Aging and Health, 14*(4), 452-466. doi: 10.1177/089826402237178

Lieberman, M. D. (2005). Principles, processes, and puzzles of social cognition: An introduction for the special issue on social cognitive neuroscience. *NeuroImage*, *28*, 745-756.

Lu, Y.-M., Jia, Z., Janus, C., Henderson, J. T., Gerlai, R., Wojtowicz, J. M., & Roder, J. C. (1997). Mice lacking metabotropic glutamate receptor 5 show impaired learning and reduced CA1 Long-Term Potentiation (LTP) but normal CA3 LTP. *The Journal of Neuroscience*, *17*(13), 5196-5205.

Luo, L., & Craik, F. I. M. (2008). Aging and memory: A cognitive approach. *Canadian Journal of Psychiatry-Revue Canadienne De Psychiatrie*, *53*(6), 346-353.

Luszczynska, A., Mazurkiewicz, M., Ziegelmann, J. P., & Schwarzer, R. (2007). Recovery self-efficacy and intention as predictors of running or jogging behavior: A cross-lagged panel analysis over a two-year period. *Psychology of Sport & Exercise*, *8*(2), 247-260.

Lytle, M. E., Vander Bilt, J., Pandav, R. S., Dodge, H. H., & Ganguli, M. (2004). Exercise level and cognitive decline: The MoVIES Project. *Alzheimer Disease Association Discord, 18*(2), 57-64.

Marks, B., Madden, D., Bucur, B., Provenzale, J., White, L., Cabeza, R. & Huettel, S. (2007). Role of aerobic fitness and aging on cerebral white matter integrity *Annual New York Academy of Science*(1097), 171-174. doi: 10.1196/annals.1379.022

Mâsse, L., Fummeler, B., Anderson, C., Mathews, C., Trost, S., Catellier, D., & Treuth, M. (2005). Accelerometer data reduction: A comparison of four reduction algorithms on select outcome variables. *Medicine & Science in Sports & Exercise*, *37*(11), S544-S554.

McAuley, E. (1993). Self-efficacy and the maintenance of exercise participation in older adults. *Journal of Behavioral Medicine, 16*(1), 103-113.

McAuley, E., & Blissmer, B. (2000). Self-efficacy determinants and consequences of physical activity. *Exercise and Sports Science Reviews, 28*(2), 85-88.

McAuley, E., Courneya, K. S., Rudolph, D. L., & Lox, C. L. (1994). Enhancing exercise adherence in middle-aged males and females. . *Preventive Medicine, 23*, 498-506.

McAuley, E., Elavsky, S., Jerome, G. J., Konopack, J. F., & Marquez, D. X. (2005). Physical activity-related well-being in older adults: Social cognitive influences. *Psychology and Aging, 20*(2), 295-302. doi: 10.1037/0882-7974.20.2.295

McAuley, E., Jerome, G. J., Elavsky, S., Marquez, D. X., & Ramsey, S. N. (2003). Predicting long-term maintenance of physical activity in older adults. *2003, 37*(2), 110-118. doi: 10.1016/S0091-7435(03)00089-6

McAuley, E., Katula, J. A., Mihalko, S. L., Blissmer, B., Duncan, T. E., Pena, M., & Dunn, E. (1999). Mode of physical activity and self-efficacy in older adults: A latent growth curve analysis. *Journal of Gerontology: Psychological Sciences, 54B*(5), 283-292.

McAuley, E., Konopack, J. F., Motl, R. W., Morris, K. S., Doerksen, S. E., & Rosengren, K. R. (2006). Physical activity and quality of life in older adults: Influence of health status and self-efficacy. *Annals of Behavioral Medicine, 31*(1), 99-103.

McAuley, E., Lox, C., & Duncan, T. E. (1993). Long-term maintenance of exercise, self-efficacy, and physiological change in older adults. *Journal of Gerontology: Psychological Sciences, 48*(4), 218-224.

McAuley, E., Mailey, E. L., Mullen, S., Szabo, A. N., Wójcicki, T. R., White, S. M., . . . Kramer, A. F. (2010). Growth trajectories of exercise self-efficacy in older adults: Influence of measures and initial status. *Health Psychology*, Advance online publication. doi: 10.1037/a0021567

McAuley, E., Morris, K. S., Motl, R. W., Hu, L., Konopack, J. F., & Elavsky, S. (2007). Long-term follow-up of physical activity behavior in older adults. *Health Psychology, 26*(3), 375-380. doi: 10.1037/0278-6133.26.3.375

McAuley, E., Mullen, S., Szabo, A. N., White, S. M., Wójcicki, T. R., Voss, M., . . . Kramer, A. F. (2011). Self-regulatory processes and exercise adherence in older adults. *American Journal of Preventative Medicine, 41*(3), 284-290. doi: 10.1016/j.amepre.2011.04.014

McAuley, E., Talbot, H. M., & Martinez, S. (1999). Manipulating self-efficacy in the exercise environment in women: Influences on affective responses. *Health Psychology, 18*(3), 288-294.

McGuire, P., Paulesu, E., Frackowiak, R., & Frith, C. (1997). Brain activity during stimulus independent thought. *Schizophrenia Research, 24*(1), 169-169.

Miller, B. L., & Cummings, J. L. (2007). *The human frontal lobes: Functions and disorders*. New York: The Guildford Press.

Montaldi, D., Spencer, T. J., Roberts, N., & Mayes, A. R. (2006). The neural system that mediates familiarity memory. *Hippocampus, 16*(5), 504-520. doi: 10.1002/hipo.20178

Monti, J. M., Hillman, C. H., & Cohen, N. J. (2012). Aerobic fitness enhances relational memory in preadolescent children: The FITKids randomized control trial. *Hippocampus*. doi: 10.1002/hipo.22023

Moody-Ayers, S. Y., Mehta, K. M., Lindquist, K., Sands, L., & Covinsky, K. E. (2005). Black–White disparities in functional decline in older persons: The role of cognitive function. *Journal of Gerontology A Biological Sciences and Medical Sciences, 60*(7), 933-939. doi: 10.1093/gerona/60.7.933

Newson, R. S. K., Eva B. (2006a). Cardiorespiratory fitness as a predictor of successful cognitive ageing. *Journal of Clinical and Experimental Neuropsychology, 28*, 9490967.

Newson, R. S. K., Eva B. (2006b). The influence of physical and cognitive activities on simple and complex cognitive tasks in older adults. *Experimental Aging Research, 32*, 341-362.

Ochsner, K. N. (2004). Current directions in social cognitive neuroscience. *Current Opinion in Neurobiology*, *14*, 254-258.

Ochsner, K. N., & Lieberman, M. D. (2001). The emergence of social cognitive neuroscience. *American Psychologist*, *56*(9), 717-734.

Okuda, J., Fujii, T., Ohtake, H., Tsukiura, T., Tanji, K., Suzuki, K., . . . Yamadori, A. (2003). Thinking of the future and past: The roles of the frontalpole and the medial temporal lobes. *NeuroImage*, *19*(4), 1369-1380. doi: 10.1016/S1053-8119(03)00179-4

Oler, J. A., & Markus, E. J. (1998). Age-related deficits on the radial maze and in fear conditioning: hippocampal processing and consolidation. *Hippocampus, 8*, 402-415.

Olson, I. R., Plotzker, A., & Ezzyat, Y. (2007). The enigmatic temporal pole: a review of findings on social and emotional processing. *Brain, 130*, 1718-1731. doi: 10.1093/brain/awm052

Park, D. C., & Reuter-Lorenz, P. (2009). The adaptive brain: Aging and neurocognitive scaffolding. *Annual Review of Psychology, 60*, 73-196. doi: 10.1146/annurev.psych.59.103006.093656

Parkash, R. S., Voss, M. W., Erickson, K. I., Lewis, J. M., Chaddock, L., Malkowski, E., . . . Kramer, A. F. (2011). Cardiorespiratory fitness and attentional control in the aging brain. *Frontiers in Human Neuroscience, 14*(4). doi: 10.3389/fnhum.2010.00229

Pate, R., Prate, M., Blair, S., Haskell, W., Macera, C., Bouchard, C.   . (1995). Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *Journal of American Medical Association, 273*(5), 402-407.

Pontifex, M. B., Hillman, C. H., & Polich, J. (2009). Age, physical fitness, and attention: P3a and P3b. *Psychophysiology, 46*(2), 379-387. doi: 10.1111/j.1469-8986.2008.00782.x

Popkirov, S. G., & Manahan-Vaughan, D. (2011). Involvement of the metabotropic glutamate receptor mGluR5 in NMDA receptor-dependent, learning-facilitated long-term depression in CA1 synapses. *Cerebral Cortex, 21*, 501-509. doi: 10.1093/cercor/bhq093

Prince, S. E., Dennis, N. A., & Cabeza, R. (2009). Encoding and retrieving faces and places: Distinguishing process- and stimulus-specific differences in brain activity. *Neuropsychologia, 47*(11), 2282-2289. doi: 10.1016/j.neuropsychologia.2009.01.021

Rajah, M. N., & D'Esposito, M. (2005). Region-specific changes in prefrontal function with age: A review of PET and fMRI studies on working and episodic memory. *Brain, 128*, 1964-1983. doi: 10.1093/brain/awh608

Ranganath, C., Cohen, M. X., Dam, C., & D'Esposito, M. (2004). Inferior temporal, prefrontal, and hippocampal contributions to visual working memory maintenance and associative memory retrieval. *Journal of Neuroscience, 24*(16), 3917-3925. doi: 10.1523/jneurosci.5053-03.2004

Ranganath, C., Heller, A., Cohen, M. X., Brozinsky, C. J., & Rissman, J. (2005). Functional connectivity with the hippocampus during successful memory formation. *Hippocampus, 15*(8), 997-1005. doi: 10.1002/hipo.20141

Resnick, S. M., Pham, D. L., Kraut, M. A., Zonderman, A. B., & Davatzikos, C. (2003). Longitudinal magnetic resonance imaging studies of older adults: A shrinking brain. *The Journal of Neuroscience, 23*(8), 3295-3301.

Riddle, W. R., DonLevy, S. C., & Lee, H. (2010). Modeling brain tissue volumes over the lifespan: Quantitative analysis of postmortem weights and in vivo MR images. *Magnetic Resonance Imaging, 28*(5), 716-720. doi: 10.1016/j.mri.2010.01.003

Rosenzweig, E. S., & Barnes, C. A. (2003). Impact of aging on hippocampal function: Plasticity, network dynamics and cognition. *Progress in Neurobiology, 63*, 143-179.

Rossion, B., Caldara, R., Seghier, M., Schuller, A.-M., Lazeyras, F., & Mayer, E. (2003). A network of occipito-temporal face-sensivitive areas besides the right middle fusiform gyrus is necessary for normal face processing. *Brain*, *126*, 2381-2395. doi: 10.1093/brain/awg241

Ruscheweyh, R., Willemer, C., Kruger, K., Duning, T., Warnecke, T., Sommer, J., . . . Flöel, A. (2011). Physical activity and memory functions: An interventional study. *Neurobiology of Aging, 32*, 1304-1319. doi: 10.1016/j.neurobiolaging.2009.08.001

Sallis, J. F., Haskell, W. L., Fortmann, S. P., Vranizan, K. M., Taylor, C. B., & Solomon, D. S. (1986). Predictors of adoption and maintenance of physical activity in a community sample. *Preventive Medicine, 15*(4), 331-341. doi: 10.1016/0091-7435(86)90001-0

Salthouse, T. A. (2003). Memory aging from 18-80. *Alzheimer Disease Association Discord, 17*, 162-167.

Salthouse, T. A. (2009). When does age-related cognitive decline begin? *Neurobiology of Aging, 30*, 507-514.

Sambataro, F., Murty, V. P., Callicott, J. H., Tan, H.-Y., Das, S., Weinberger, D. R., & Mattay, V. S. (2010). Age-related alterations in default mode network: Impact on working memory performance. *Neurobiology of Aging, 31*, 839-852. doi: 10.1016/j.neurobiolaging.2008.05.022

Schacter, D. L., Addis, D. R., & Buckner, R. L. (2007). Remembering the past to imagine the future: The prospective brain. *Nature Reviews Neuroscience, 8*, 657-661. doi: 10.1038/nrn2213

Schmitz, T. W., & Johnson, S. C. (2006). Self-appraisal decisions evoke dissociated dorsal-ventral aMPFC networks. *NeuroImage, 30*, 1050-1058.

Schneider, A., Kruger, C., Steigledger, T., Weber, D., Pitzer, C., Laage, R., . . . Schäbatz, W. R. (2005). The hematopoietic factor G-CSF is a neuronal ligand that counteracts programmed cell death and drives neurogenesis. . *Journal of Clinical Investigation 115*, 2083-2098. doi: 10.1172/JCI23559

Serra, M. J., Dunlosky, J., & Hertzog, C. (2008). Do older adults show less confidence in their monitoring of learning? *Experimental Aging Research, 34*(4), 379-391. doi: 10.1080/03610730802271898

Sheikh, J. I., & Yesavage, J. A. (1986). Geriatric Depression Scale (GDS): Recent evidence and development of a shorter version. *Clinical Gerontology : A Guide to Assessment and Intervention* (pp. 165-173). New York: The Haworth Press.

Shepard, R. J., & Bouchard, C. (1994). Population evaluations of health related fitness from perceptions of physical activity and fitness. *Canadian journal of applied physiology, 19*(2), 151-173.

Shepard, R. J., & Bouchard, C. (1995). Relationship between perceptions of physical activity and health-related fitness. *The Journal of sports medicine and physical fitness, 35*(3), 149-158.

Small, S. A., Tsai, W. Y., DeLaPaz, R., Mayeux, R., & Stern, Y. (2002). Imaging hippocampal function across the human life span: Is memory decline normal or not? *Annals of Neurology, 51*, 290-295. doi: 10.1002/ana/10105

Smith, P. J., Blumenthal, J. A., Hoffman, B. M., Cooper, H., Strauman, T. A., Welsh-Bohmer, K., . . . Sherwood, A. (2010). Aerobic exercise and neurocognitive performance: A meta-analytic review of randomized controlled trials. *Psychosomatic Medicine, 72*(3), 239-252. doi: 10.1097/PSY.0b013e3181d14633

Smith, S. M., Zhang, Y., Jenkinson, M., Chen, J., Mathews, P. M., Federico, A., & De Stefano, N. (2002). Accurate, robust and automated longitudinal and cross-sectional brain change analysis. *NeuroImage, 17*(1), 479-489.

Spirduso, W. W., & Clifford, P. (1978). Replication of age and physical activity effects on reaction time movement time. *Journal of Gerontology, 33*, 23-30.

Squire, L. R. (1987). *Memory and brain*. New York: Oxford University Press.

Stark, C. E. L., & Squire, L. R. (2001). When zero is not zero: The problem of ambiguous baseline conditions in fMRI. *Proceedings of the National Academy of Sciences, 98*(22), 12760-12766. doi: 10.1073/pnas.221462998

Szabo, A. N., McAuley, E., Erickson, K. I., Voss, M., Prakash, R., Mailey, E. L., . . . Kramer, A. F. (2011). Cardiorespiratory fitness, hippocampal volume and memory complaints in older adults. *Neuropsychology, 25*(5), 545-553. doi: 10.1037/a0022733

Taylor, A. H. (2000). Physical activity, anxiety and stress. In S. J. H. Biddle, K. R. Fox & S. H. Boutcher (Eds.), *Physical Activity and Psychological Well Being* (pp. 10 - 33). London: Routledge.

Teyler, T. J., Hamm, J. P., Clapp, W. C., Johnson, B. W., Corballis, M. C., & Kirk, I. J. (2005). Long-term potentiation of human visual evoked responses. *European Journal of Neuroscience, 21*, 2045-2050.

Themanson, J. R., Hillman, C. H., McAuley, E., Buck, S. M., Doerksen, S. E., Morris, K. S., & Pontifex, M. B. (2008). Self-efficacy effects on neuroelectric and behavioral indices of action monitoring in older adults. *Neurobiology of Aging*, *29*, 1111-1121.

Themanson, J. R., Pontifex, M. B., Hillman, C. H., & McAuley, E. (2011). The relation of self-efficacy and error-related self regulation. *International Journal of Psychophysiology*, *80*(1-10). doi: 10.1016/j.ijpsycho.2011.01.005

Toyoda, H., Zhao, M. G., & Zhuo, M. (2006). NMDA receptor-dependent long-term depression in the anterior cingulate cortex. *Reviews in the Neuroscience, 17*(403-413).

Tucker-Drob, E. M. (2011). Neurocognitive functions and everyday functions change together in old age. *Neuropsychology, Epub ahead of print*. doi: 10.1037/a0022348

Tudor-Locke, C., Ainsworth, B. E., Thompson, R. W., & Matthews, C. E. (2002). Comparison of pedometer and accelerometer measures of free-living physical activity. *Medicine & Science in Sports & Exercise, 34*(12), 2045-2051.

Tulving, E., & Craik, F. I. M. (Eds.). (2000). *Episodic Memory: From Mind to Brain*. New York: Oxford Univeristy Press.

United Nations Populations Division (2010). Population Aging and Developement. Retrieved 7/25/10, 2010, from www.un.org/esa/population/

van Boxtel, M. P. J., Paas, F. G. W. C., Houx, P. J., Adam, J. J., Teeken, J. C., & Jolles, J. (1997). Aerobic capacity and cognitive performance in a cross-sectional aging study. *Medicine & Science in Sports & Exercise, 29*(10), 1357-1365.

van Overwalle, F. (2009). Social cognition and the brain: A meta-analysis. *Human Brain Mapping, 30*(3), 829-858. doi: 10.1002/hbm.20547

van Praag, H., Kempermann, G., & Gage, F. H. (1999). Running increases cell proliferation and neurogenesis in the adult mouse dentate gyrus. *Nature and Neuroscience, 2,* 266-270.

van Uffelen, J. G. Z., Chin A Paw, M. J. M., Hopman-Rock, M., & van Mechelen, W. (2008). The effects of exercise on cognition in older adults with and without cognitive decline: A systematic review. *Journal of Clinical Sports Medicine, 18*(6), 486-500.

Vaynman, S., & Gomez-Pinilla, F. (2005). License to run: exercise impacts functional plasticity in the intact and injured central nervous system by using neurotrophins. *Neurorehabilitation and Neural Repair, 19,* 283-295.

Verbrugge, L. M., & Jette, A. M. (1994). The disablement process. *Social Science & Medicine, 38*(1), 1-14.

Voss, M., Erickson, K., Prakash, R. S., Chaddock, L., Malkowski, E., Alves, H., . . . Kramer, A. F. (2010). Functional connectivity: A source of variance in the association between cardiorespiratory fitness and cognition? *Neuropsychologia, 48*(5), 1394-1406. doi: 10.1016/j.neuropsychologia.2010.01.005

Voss, M., Prakash, R. S., Erickson, K., Basak, C., Chaddock, L., Kim, J. S., . . . Kramer, A. F. (2010). Plasticity of brain networks in a randomized intervention trial of exercise training in older adults. *Frontiers in Aging Neuroscience, 2*(32). doi: 10.3389/fnagi.2010.00032

Wall, P. M., & Messier, C. (2001). The hippocampal formation- orbitomedial prefrontal cortex circuit in the attentional control of active memory. *Behavioural Brain Research, 127*, 99-117.

Walter, H., Adenzato, M., Ciaramidaro, A., Enrici, I., Pia, L., & Bara, B. G. (2004). Understanding Intentions in social interaction: The role of the anterior paracingulate cortex. *Journal of Cognitive Neuroscience, 16*(10), 1854-1863.

Washburn, R. A., McAuley, E., Katula, J., Mihalko, S. L., & Boileau, R. A. (1999). The physical activity scale for the elderly (PASE): Evidence for validity. *Jounal of Clinical Epidemiology, 52*(7), 643-651.

Washburn, R. A., Smith, K. W., Jette, A. M., & Janney, C. A. (1993). The Physical Activity Scale for the Elderly (PASE): Development and evaluation. *Journal of Clinical Epidemiology, 46*(153-162).

Wells, G. D., & Esopenko, C. (2008). Memory self-efficacy, aging, and memory performance: The roles of effort and persistence. *Educational Gerontology, 34*(6), 520-530. doi: 10.1080/03601270701869386

West, R. L., Bagwell, D. K., & Dark-Freudeman, A. (2008). Self-efficacy and memory aging: The impact of a memory intervention based on self-efficacy. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition, 15*(3), 302-329.

Weuve, J., Kang, J. H., Manson, J. E., Breteler, M. M. B., Ware, J. H., & Grodstein, F. (2004). Physical activity. including walking, and cognitive function in older women. *2004, 292*(12), 1454-1461.

Wheeler, M. E., Petersen, S. E., & Buckner, R. L. (2000). Memory's echo: Vivid remembering reactivates sensory-specific cortex. *Proceedings of the National Academy of Sciences of the United States of America, 97*(20), 11125-11129.

Windsor, T. D., & Anstey, K. J. (2008). A longitudinal investigation of perceived control and cognitive performance in young, midlife and older adults. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition, 15*(6), 744-763.

Wood, R., & Bandura, A. (1989). Impact of conceptions of ability on self-regulatory mechanisms and complex decision-making. *Journal of Personality and Social Psychology*, *56*(3), 407-415.

Yaffe, K., Barnes, D., Nevitt, M., Lui, L. Y., & Covinsky, K. (2001). A prospective study of physical activity and cognitive decline in elderly women *Archives of Internal Medicine, 161*, 1703-1708.

Yonelinas, A. P., Widarnan, K., Mungas, D., Reed, B., Weiner, M. W., & Chui, H. C. (2007). Memory in the aging brain: Doubly dissociating the contribution of the hippocampus and entorhinal cortex. *Hippocampus*, *17*, 1134-1140. doi: 10.1002/hipo.20341

Zacks, R. T., Hasher, L., & Li, K. Z. H. (2000). Human Memory. In F. I. M. Craiks & T. A. Salthouse (Eds.), *The Handbook on Aging and Cognition* (pp. 293-357). Mahwah: Lawrence Erlbaum Associates Publishers.

Zelinski, M., & Gilewski, M. J. (2004). A 10-item rasch model memeory self-efficacy scale. *Aging Ment Health*, *8*(4), 293-306. doi: 10.1080/13607860410001709665

Zelinski, M., Gilewski, M. J., & Anthony-Bergstone, C. R. (1990). Memory functioning questionaire: Concurrent validity with memory performance and self-report memory failures. *Psychol Aging, 5*(3), 388-399.

Zhu, L., Guo, X., Li, J., Zheng, L., Wang, Q., & Yang, Z. (2011). Hippocampal activity is associated with self-descriptiveness effect in memory, whereas self-reference effect in memory depends on medial prefrontal activity. *Hippocampus*. doi: 10.1002/hipo.20994

Chapter 7: Tables

Table 1

Sample characteristics means and standard deviations

	Total sample	Low-active	High-active	*t*	*p*
N	46	23	23		
N of females	32	16	16		
Age	65.33 (4.3)	65.35 (4.68)	65.26 (4.05)	-.034	.973
Education (College or >)	73.9%	56.5%	91.3%	1.965	.057
Are you in a life long learning program?	8.6%	0.0%	17.4%	2.152	.043
BMI	27.6 (5.1)	30.53 (4.79)	24.82 (3.61)	-4.618	.000
Physical activity counts per day (epochs)	267,350 (98,655.9)	221,060 (67,597.5)	313,640 (104,202)	3.575	.001
MVPA counts per day (epochs)	27.86 (19.45)	19.39 (10.78)	36.34 (22.53)	3.254	.003
VO_2 (mL/kg)	25.22 (8.97)	21.02 (5.54)	29.10 (9.56)	3.562	.001
F of F total score	47.74 (10.63)	45.35 (11.23)	49.61 (9.78)	1.372	.177
MCI present ability subscale	15.78 (4.10)	15.35 (4.42)	16.22 (3.81)	.715	.479
MCI potential improvement subscale	16.26 (3.80)	15.35 (3.36)	17.17 (2.90)	1.657	.106
MCI effort utility subscale	16.30 (3.30)	15.86 (3.36)	16.74 (3.26)	.890	.378

Table 1 (cont.)

Sample characteristics means and standard deviations continued

	Total sample	Low-active	High-active	*t*	*p*
MCI inevitable decrement subscale	9.74 (3.97)	9.86 (3.96)	9.61 (4.06)	-.221	.826
MSE score (%)	42.75% (22.67)	46.38% (24.08)	39.13% (21.09)	-1.086	.283
Mean MSE RT (ms)	758.129 (123.994)	755.446 (107.925)	760.813 (140.660)	.145	.885
Mean MSE yes RT (ms)	721.314 (295.639)	697.891 (396.873)	744.736 (141.853)	.533	.597
Mean MSE no RT (ms)	704.162 (292.926)	651.277 (372.338)	757.046 (176.147)	1.231	.227
NSE score (% yes responses)	29.9% (14.2)	10.94% (2.28)	16.52% (3.44)	1.447	.155
Mean NSE RT (ms)	808.841 (168.864)	776.498 (169.019)	841.184 (166.046)	1.309	.197
NSE yes RT (ms)	817.671 (280.260)	754.081 (231.025)	881.261 (314.379)	1.563	.125
NSE no RT (ms)	812.977 (167.960)	790.932 (163.258)	835.022 (166.046)	.888	.379
Proportion of correct responses on memory task (%)	70.33% (8.85)	69.98% (9.10)	70.69% (8.77)	.270	.788
d prime	1.22 (.61)	1.16 (.61)	1.27 (.62)	.597	.553

Note. BMI = body mass index; MVPA= moderate to vigorous physical activity; VO_2= cardiorespiratory fitness (mL/kg); F of F= frequency of forgetting; MCI = memory controllability inventory; MSE = memory self-efficacy; RT = reaction time; NSE = non self-efficacy

Table 2

Sample characteristics means and standard deviations for MVPA groups

	Total sample	Low-MVPA	High-MVPA	*t*	*p*
N	46	28	18		
N of females	32	19	13	.307	.760
Age	65.33 (4.3)	66.29 (4.814)	63.83 (2.895)	-2.156	.037
Education (College or >)	73.9%	57.1%	100%	3.546	.001
Are you in a life long learning program?	8.6%	7.1%	1.5%	.457	.650
BMI	27.6 (5.1)	28.56 (5.16)	26.11 (4.99)	-1.591	.119
Physical activity counts per day (epochs)	267,350 (98,655.9)	212,340 (61,134.8)	352,920 (84,215.6)	6.121	.000
MVPA counts per day (epochs)	27.86 (19.45)	15.13 (7.38)	47.68 (15.25)	8.445	.000
VO_2 (mL/kg)	25.22 (8.97)	21.44 (6.77)	31.10 (8.97)	3.909	.001
F of F total score	47.74 (10.63)	44.67 (10.14)	51.83 (10.14)	2.335	.024
MCI present ability subscale	15.78 (4.10)	15.10 (3.85)	16.83(4.36)	1.407	.166
MCI potential improvement subscale	16.26 (3.80)	15.46 (3.58)	17.50 (3.91)	1.814	.077

Table 2 (cont.)

Sample characteristics means and standard deviations for MVPA groups continued

	Total sample	Low-MVPA	High-MVPA	*t*	*p*
MCI effort utility subscale	16.30 (3.30)	15.78 (3.01)	17.11 (3.66)	1.339	.188
MCI inevitable decrement subscale	9.74 (3.97)	10.35 (3.36)	8.77 (4.69)	-.1.328	.191
MSE score (%)	42.75% (22.67)	39.29% (24.22)	48.15% (19.45)	1.304	.199
Mean MSE RT (ms)	758.129 (123.994)	740.961 (98.544)	784.836 (155.028)	1.176	.246
Mean MSE yes RT (ms)	721.314 (295.639)	680.689 (360.058)	784.508 (136.053)	1.167	.249
Mean MSE no RT (ms)	704.162 (292.926)	669.160 (341.788)	758.608 (190.894)	1.011	.318
NSE score (% yes responses)	29.9% (14.2)	27.53% (15.30)	33.8% (11.60)	1.482	.145
Mean NSE RT (ms)	808.841 (168.864)	768.547 (154.458)	871.521 (175.372)	2.093	.042
NSE yes RT (ms)	817.671 (280.260)	793.401 (330.894)	855.426 (177.591)	.729	.470
NSE no RT (ms)	812.977 (167.960)	776.769 (149.884)	869.299 (182.967)	1.874	.068
Proportion of correct responses on memory task (%)	70.33% (8.85)	68.37% (9.76)	73.38% (6.28)	1.929	.060
d prime	1.22 (.61)	1.10 (.68)	1.39 (.42)	1.622	.112

Note. BMI = body mass index; MVPA= moderate to vigorous physical activity; VO_2= cardiorespiratory fitness (mL/kg); F of F= frequency of forgetting; MCI = memory controllability inventory; MSE = memory self-efficacy; RT = reaction time; NSE = non self-efficacy

Table 3

All selected ROIs

A. Selected MSE >NSE ROIs

ROI	X	Y	Z	Z value
Left Retrosplenial	-6	-46	10	2.51
Left ACC	-6	10	40	3.07
Left dMPFC	-52	2	40	3.62
Left TPJ	-60	-46	20	3.62
Left vMPFC	-54	8	0	4.17

B. Other MSE > NSE ROIs

ROI	X	Y	Z	Z value
Left OCC	-32	-86	18	4.79
Left PrG	-24	-20	76	4.52
Left TP	-54	14	-8	4.49
Left SFG	-8	10	72	4.16
Right TOF	36	-42	-20	4.14
Left PAC	-6	14	40	3.65
Right PAC	6	10	44	3.91

Table 3 (cont.)

All selected ROIs continued.

C. Selected MSE > rest ROIs				
ROI	X	Y	Z	Z value
Left OP	-14	-100	-6	6.15
Right OP	16	-98	-4	6.13
Left PrG	-26	-24	70	5.66
Right FP	2	58	16	5.64
Left FP	-4	56	26	5.55

D. Selected NSE > rest ROIs

ROI	X	Y	Z	Z value
Right FP	18	52	28	5.29
Left OP	-14	-102	-2	4.04
Right OP	18	-98	-2	4.44

Note. ROI = region of interest; MSE = memory self-efficacy; NSE = non self-efficacy task; ACC = anterior cingulate cortex; dMPFC = dorsal medial prefrontal cortex, TPJ = temporal parietal junction; vMPFC= ventral medial prefrontal cortex; OCC = occipital cortex; PrG = precentral gyrus; PAC = paracingulate cortex; TP = temporal pole; SFG = superior frontal gyrus; TOF = temporal occipital fusiform; OP = occipital pole; FP = frontal pole

Table 4

Correlation between education, life-long-learning membership, memory performance, and self-referential ROIs

	1	2	3	4	5	6	7	8	9
1 Education	---	.071	.240	.217	.043	.360*	-.117	-.166	-.075
2 Life-Long		---	-.016	.041	.147	-.140	.129	-.159	.254
3 Proportion Correct Responses			---	.973**	.078	.082	-.292*	.001	-.049
4 *d* Prime				---	.126	.102	-.259	-.027	-.054
5 L. Retrosplenial					---	.178	.428**	.252	.299*
6 L. ACC						---	.021	.149	-.136
7 L. dMPFC							---	.093	.247
8 L. TPJ								---	.358*
9 L. vMPFC									---

Note. Life-Long = Are you in a life long learning program?; L = left; ACC = anterior cingulate cortex; dMPFC = dorsal medial prefrontal cortex, TPJ = temporal parietal junction; vMPFC= ventral medial prefrontal cortex
* Significant at p > .05; significant at ** p > .01

Table 5

Correlation between education, life-long-learning membership, memory performance, and non-hypothesized ROIs

	1	2	3	4	5	6	7	8	9	10	11
1 Education	---	.071	.240	.217	.019	.105	-.029	.046	-.123	-.106	.009
2 Life-Long		---	-.016	.041	.191	.470**	.083	.448**	-.001	.320*	.189
3 Proportion Correct Responses			---	.973**	.214	-.125	-.122	-.045	-.033	-.178	-.146
4 *d* Prime				---	.188	-.116	-.126	-.032	-.053	-.156	-.155
5 L. OCC					---	.260	.483**	.494**	.522**	.201	.123
6 L. PrG						---	.297*	590**	.016	.359*	.479**
7 L. TP							---	.420**	.586**	.361*	.355*
8 L. SFG								---	.243	.395*	.363*
9 R. TOF									---	.259	.112
10 L. PAC										---	.832**
11 R. PAC											---

Note: Life-Long = Are you in a life long learning program?; L = left; R = right; OCC = occipital cortex; PrG = precentral gyrus; TP = temporal pole; SFG = superior frontal gyrus: TOF = temporal occipital fusiform; PAC = paracingulate cortex
* Significant at $p > .05$; significant at ** $p > .01$

Table 6

Mean brain activity differences by physical activity group

ROI	Total Sample	Low-active	High -active	t	*p*
Left Retrosplenial	.017	-.016	.049	.367	.716
Left ACC	-.028	-.052	-.003	.654	.517
Left dMPFC	-.075	.033	-.183	-1.980	.054
Left TPJ	-.085	-.032	-.138	-1.232	.225
Left vMPFC	-.186	-.203	-.168	.326	.746

Note. ROI = region of Interest; ACC = anterior cingulate cortex; dMPFC = dorsal medial prefrontal cortex, TPJ = temporal parietal junction; vMPFC= ventral medial prefrontal cortex

Table 7

Mean brain activity differences by MVPA group

ROI	Total Sample	Low-MVPA	High -MVPA	t	*p*
Left Retrosplenial	.017	.029	-.002	-.173	.863
Left ACC	-.028	-.060	.023	1.295	.203
Left dMPFC	-.075	.033	-.243	-2.524	.015
Left TPJ	-.085	-.091	-.077	.154	.878
Left vMPFC	-.186	-.159	-.228	-.630	.532

Note. MVPA= moderate to vigorous physical activity; ROI = region of Interest; ACC = anterior cingulate cortex; dMPFC = dorsal medial prefrontal cortex, TPJ = temporal parietal junction; vMPFC= ventral medial prefrontal cortex

Table 8

Correlation between memory performance, and self-referential ROIs

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1.Education	---	.071	.240	.217	.239	.071	.149	.089	.267	.017	.386**	.499**	.411**	.043	.360*	-.117	-.166	-.075
2 Life-Long		---	-.016	.041	-.029	.055	-.123	-.097	.122	.028	.123	.176	.267	.147	-.140	.129	-.159	.254
3 Proportion Correct Responses			---	.973**	.333*	.010	-.077	-.097	.154	.170	.251	.266	.262	.078	.082	-.292*	.001	-.049
4 *d* Prime				---	.336	-.012	-.106	-.089	.127	.137	.256	.252	.237	.126	.102	-.259	-.027	-.054
5 FOF total					---	.567**	.480**	-.562**	.571**	.289*	.396**	.361*	.327*	-.059	.328*	-.364	-.003	.025
6 MCI present ability						---	.701**	-.603**	.845**	.242	.165	.171	.120	-.198	.095	-.144	.002	.026
7 MCI utility							---	-.361	.754**	.360*	-.011	.061	.057	-.290	.068	-.270	-.066	-.082
8 MCI inevitable decrement								---	-.563**	-.371*	-.234	-.252	-.214	.214	.025	.192	-.093	.083
9 MCI potential improvement									---	.228	.203	.275	.234	-.192	.003	-.208	-.039	-.012
10 MSE %										---	.067	.118	.251	.143	.054	-.049	-.024	-.066
11 VO_2											---	.683**	.554	.133	.135	-.210	.197	.143
12 Total physical activity												---	.871**	.130	.081	-.243	.156	-.030

Table 8 (cont.)

Correlation between memory performance, and self-referential ROIs continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	19
13 Total MVPA													---	.128	.078	-.314*	.026	-.069
14 L. Retrosplenial														---	.178	.428**	.252	.299*
15 L. ACC															---	.021	-.149	-.136
16 dMPFC																---	.093	.247
17 L. TPJ																	---	.358*
18 L. vMPFC																		---

Note. Life-Long = Are you in a life long learning program?; F of F= frequency of forgetting; MCI = memory controllability inventory; MSE = memory self-efficacy MVPA= moderate to vigorous physical activity; VO_2= cardiorespiratory fitness (mL/kg); ACC = anterior cingulate cortex; dMPFC = dorsal medial prefrontal cortex, TPJ = temporal parietal junction; vMPFC= ventral medial prefrontal cortex

* significant at p > .05; significant at ** p > .01

Table 9

Influence of physical activity, cardiorespiratory fitness, self-efficacy and brain activation on proportion of correct responses

	ß	P	R^2
Education	.127	.437	.013
F of F score	.199	.237	.030
dMPFC activity	-.175	.276	.025
Total MVPA	.061	.743	.002
VO_2 (mL/kg)	.053	.774	.002

Note. F of F = frequency of forgetting; dMPFC = dorsal medial prefrontal cortex; MVPA = moderate to vigorous physical activity; VO_2 = cardiorespiratory fitness (mL/kg)

Table 10

Influence of physical activity, cardiorespiratory fitness, self-efficacy and brain activation on d prime

	ß	p	R^2
Education	.102	.533	.008
F of F score	.215	.205	.035
dMPFC activity	-.141	.383	.016
Total MVPA	.031	.867	.001
VO_2 (mL/Kg)	.088	.636	.005

Note. F of F = frequency of forgetting; dMPFC = dorsal medial prefrontal cortex; MVPA = moderate to vigorous physical activity; VO_2 = cardiorespiratory fitness (mL/kg)

Chapter 8: Figures

Figure 1

Social Cognitive Theory: Triadic Reciprocity

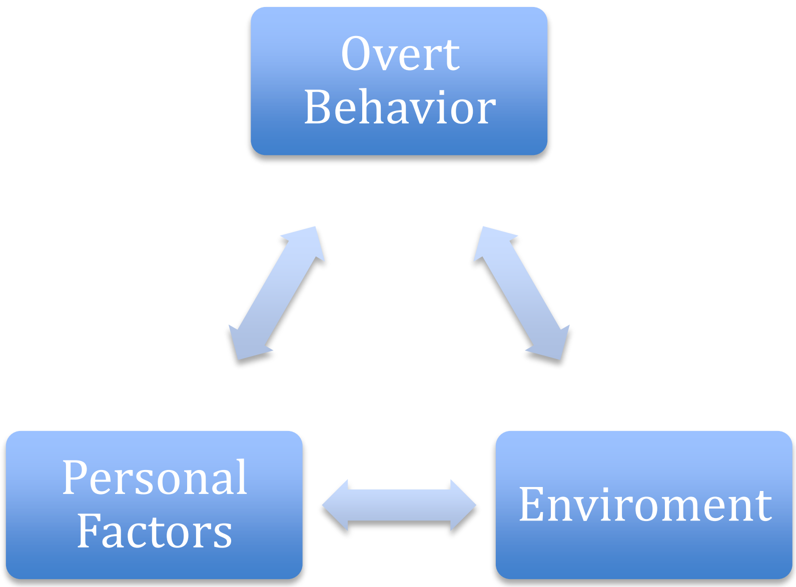


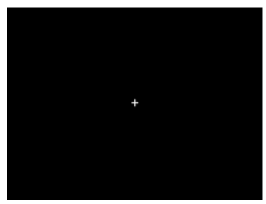
Figure 2

Example Encoding and Recognition trial stimuli

Encoding

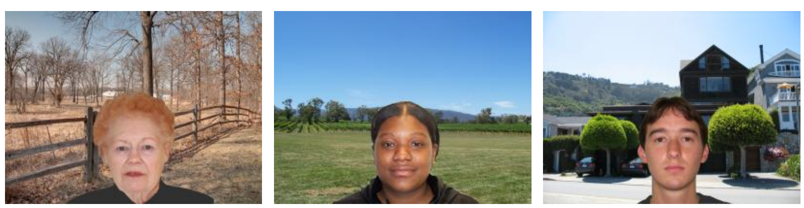
“yes” “no” “yes”

Delay



20 s delay

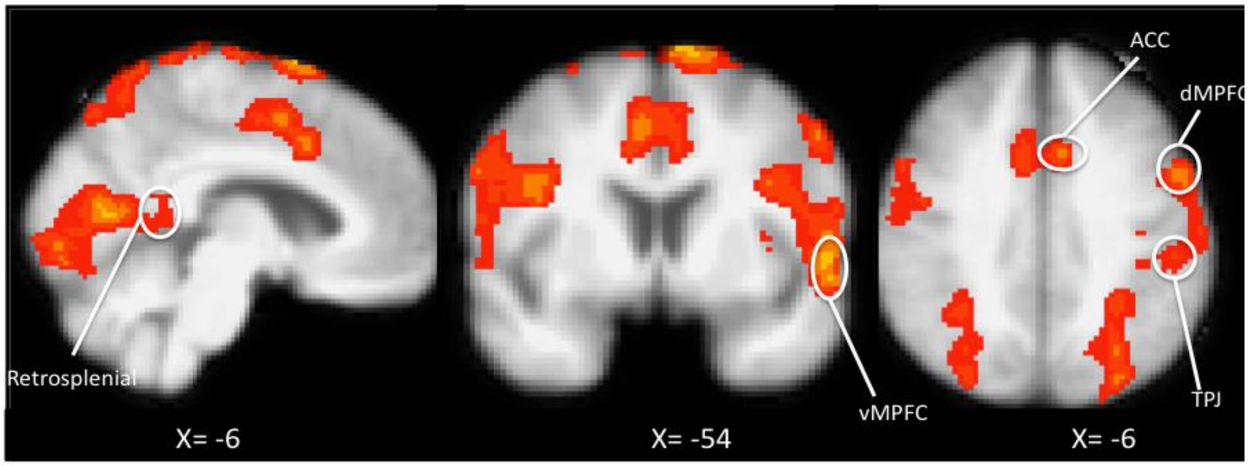
Recognition



“no” “yes” “no”

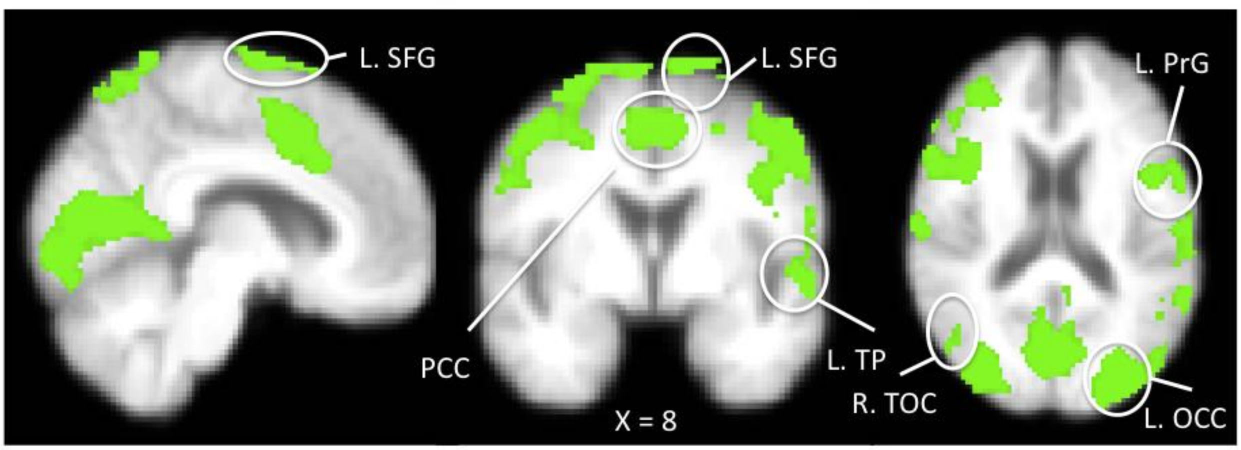
Figure 3

A. Active brain regions during self-reference task (MSE > NSE contrast)



* Images are presented in radiological orientation
Note. ACC = anterior cingulate cortex; dMPFC = dorsal medial prefrontal cortex, TPJ = temporal parietal junction; vMPFC= ventral medial prefrontal cortex

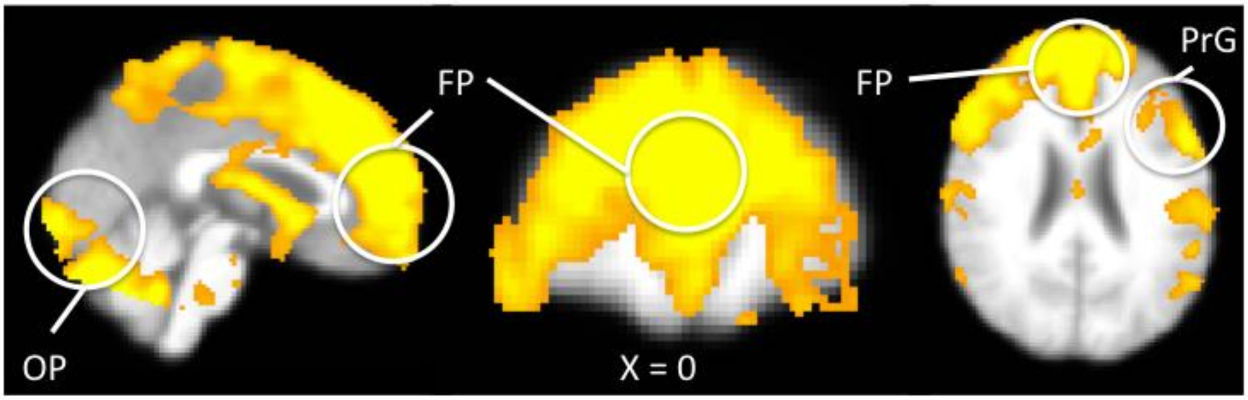
B. Other active brain regions during self-reference task (MSE > NSE contrast)



* Images are presented in radiological orientation
Note. L = left; R = right; OCC = occipital cortex; PrG = precentral gyrus; TP = temporal pole; SFG = superior frontal gyrus: TOF = temporal occipital fusiform; PAC = paracingulate cortex

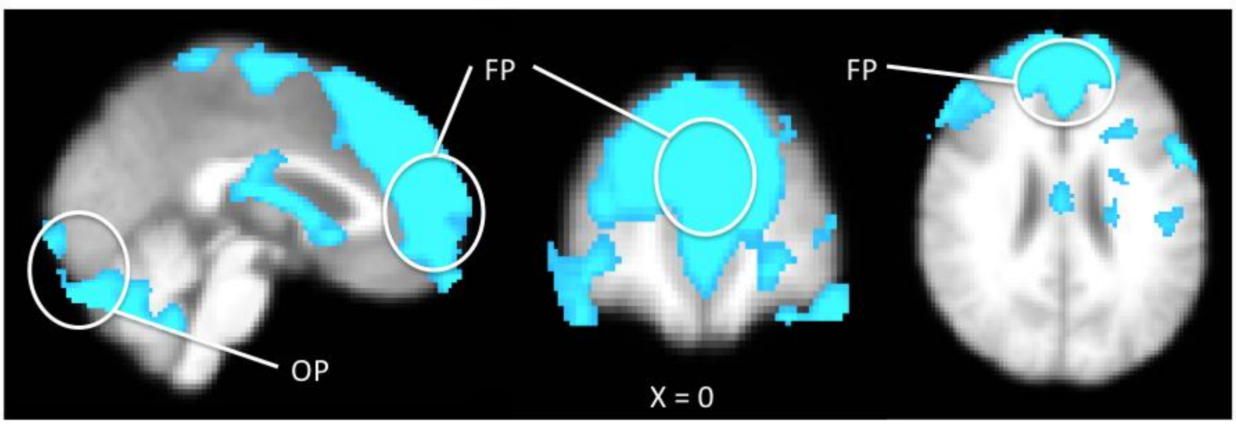
Figure 3 (cont.)

C. Active brain regions during self-reference task (MSE > rest contrast)



* Images are presented in radiological orientation
Note. OP = occipital pole; FP = frontal pole; PrG = precentral gyrus

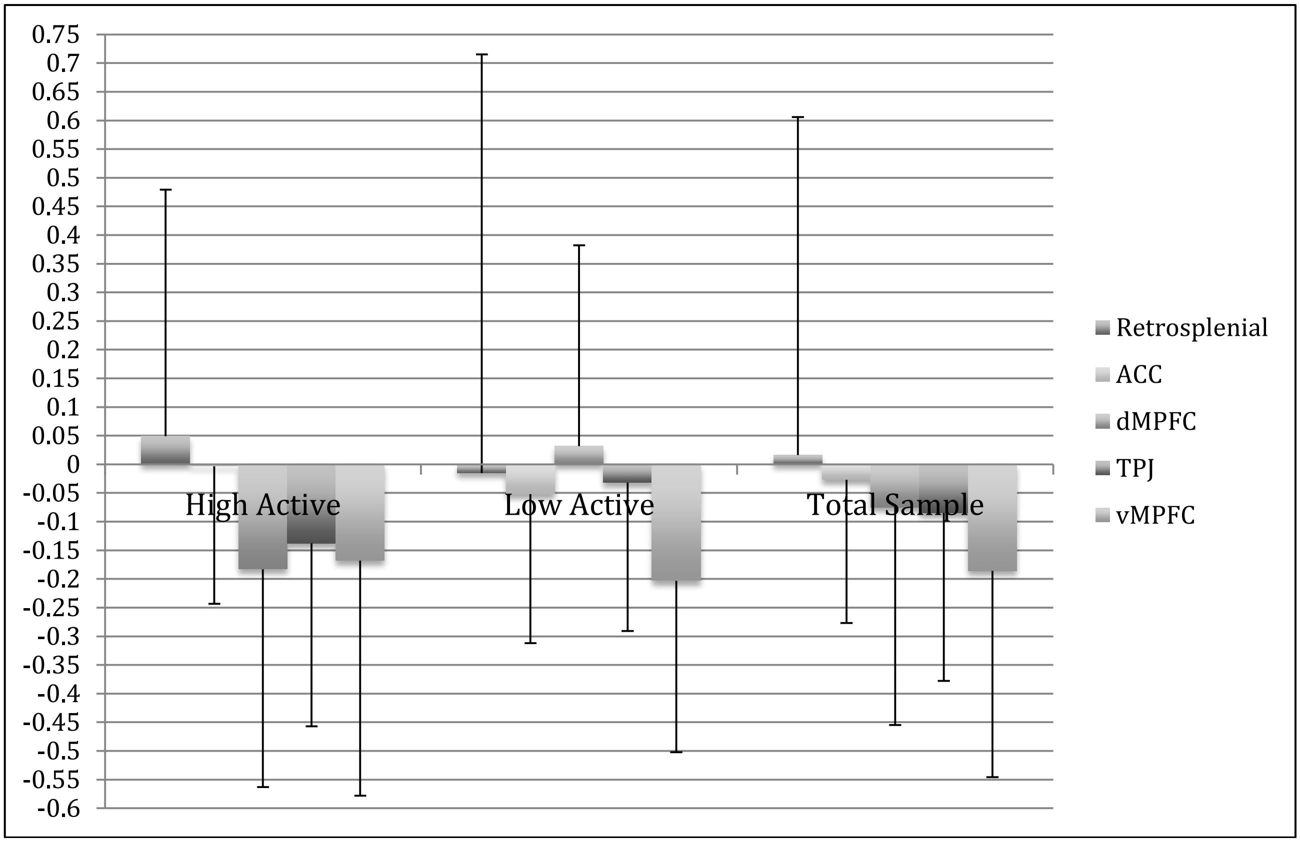
D. Active brain regions during non self-reference task (NSE > rest contrast)



* Images are presented in radiological orientation
Note. OP = occipital pole; FP = frontal pole

Figure 4

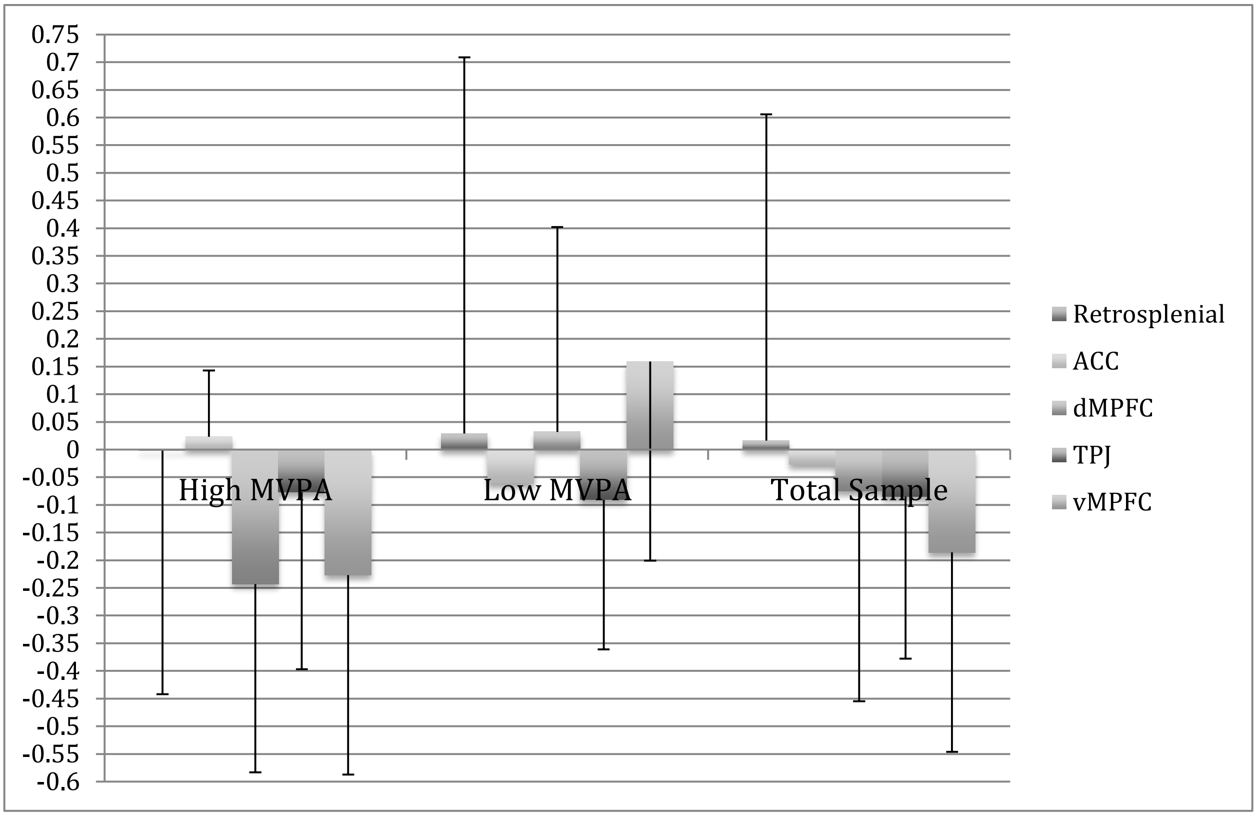
Mean brain activity by physical activity group



Note. ACC = anterior cingulate cortex; dMPFC = dorsal medial prefrontal cortex, TPJ = temporal parietal junction; vMPFC= ventral medial prefrontal cortex

Figure 5

Mean brain activity by MVPA group



Note. MVPA = moderate to vigorous physical activity; ACC = anterior cingulate cortex; dMPFC = dorsal medial prefrontal cortex, TPJ = temporal parietal junction; vMPFC= ventral medial prefrontal cortex

Appendix A

Memory Self-Efficacy (MSE) Task Items

Note: Items appeared in random order and all items were Yes or No response

1. I am confident that I can recognize 1 of 24 face-scene pairs.
2. I am confident that I can recognize 2 of 24 face-scene pairs.
3. I am confident that I can recognize 3 of 24 face-scene pairs.
4. I am confident that I can recognize 4 of 24 face-scene pairs.
5. I am confident that I can recognize 5 of 24 face-scene pairs.
6. I am confident that I can recognize 6 of 24 face-scene pairs.
7. I am confident that I can recognize 7 of 24 face-scene pairs.
8. I am confident that I can recognize 8 of 24 face-scene pairs.
9. I am confident that I can recognize 9 of 24 face-scene pairs.
10. I am confident that I can recognize 10 of 24 face-scene pairs.
11. I am confident that I can recognize 11 of 24 face-scene pairs.
12. I am confident that I can recognize 12 of 24 face-scene pairs.
13. I am confident that I can recognize 13 of 24 face-scene pairs.
14. I am confident that I can recognize 14 of 24 face-scene pairs.
15. I am confident that I can recognize 15 of 24 face-scene pairs.
16. I am confident that I can recognize 16 of 24 face-scene pairs.
17. I am confident that I can recognize 17 of 24 face-scene pairs.
18. I am confident that I can recognize 18 of 24 face-scene pairs.
19. I am confident that I can recognize 19 of 24 face-scene pairs.
20. I am confident that I can recognize 20 of 24 face-scene pairs.

21. I am confident that I can recognize 21 of 24 face-scene pairs.

22. I am confident that I can recognize 22 of 24 face-scene pairs.

23. I am confident that I can recognize 23 of 24 face-scene pairs.

24. I am confident that I can recognize 24 of 24 face-scene pairs.

Appendix B

Non Self-Referential (NSE) Task Items

Note: Items appeared in random order and all items were Yes or No response

1. I am confident that it will rain 1 of 24 days this month.
2. I am confident that it will rain 2 of 24 days this month.
3. I am confident that it will rain 3 of 24 days this month.
4. I am confident that it will rain 4 of 24 days this month.
5. I am confident that it will rain 5 of 24 days this month.
6. I am confident that it will rain 6 of 24 days this month.
7. I am confident that it will rain 7 of 24 days this month.
8. I am confident that it will rain 8 of 24 days this month.
9. I am confident that it will rain 9 of 24 days this month.
10. I am confident that it will rain 10 of 24 days this month.
11. I am confident that it will rain 11 of 24 days this month.
12. I am confident that it will rain 12 of 24 days this month.
13. I am confident that it will rain 13 of 24 days this month.
14. I am confident that it will rain 14 of 24 days this month.
15. I am confident that it will rain 15 of 24 days this month.
16. I am confident that it will rain 16 of 24 days this month.
17. I am confident that it will rain 17 of 24 days this month.
18. I am confident that it will rain 18 of 24 days this month.
19. I am confident that it will rain 19 of 24 days this month.
20. I am confident that it will rain 20 of 24 days this month.

21. I am confident that it will rain 21 of 24 days this month.

22. I am confident that it will rain 22 of 24 days this month.

23. I am confident that it will rain 23 of 24 days this month.

24. I am confident that it will rain 24 of 24 days this month.